THE GEOLOGY OF THE NANDEWAR MOUNTAINS.

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(Plates xlvi.-lii.)

A. General Geology and Physiography.

1. Introduction.

The mountains described under this name lie in the Counties of Nandewar, Murchison, Jamieson and Darling, and are situated between the townships of Narrabri, Barraba and Bingera. In a former paper I made brief mention of this group of mountains (These Proceedings, 1906, p.235); since its publication I have spent two more months in the district, and am in consequence able to give a more detailed account.

The Nandewar Mountains in their physiographic features bear close resemblance to the Warrumbungles, and they are exceedingly rich in rock-types.

The region is, from a geological standpoint, practically unexplored, though parts have been visited by Mr. E. F. Pittman, A.R.S.M., Government Geologist; and by Professor T. W. E. David, B.A., F.R.S. His Honor Judge Docker has visited practically all parts of this region to take scenic photographs, and is probably better acquainted with it than anyone who has made casual trips to it.

2. Petrography.

The rocks of the Nandewar Mountains may be conveniently divided into Sedimentary, Metamorphic, and Igneous.

The *Sedimentary Rocks* include (a) Carboniferous conglomerates and grits, chiefly in the S.E. and E. portions of the area; (b) Permo-Carboniferous conglomerates, grits, sandstones and shales, forming the country rock in the area where volcanic activity has been greatest. The Permo-Carboniferous rocks continue westward under the plains, and are also the most important formation in the Rocky Creek district. (c) Trias-Jura rocks, forming mesas capping the Permo-Carboniferous. (d) Tertiary deposits.

The *Metamorphic Series* includes (a) slates, cherts and schists of Devonian age associated with the Carboniferous rocks in the S.E. (at Coolah Station). (b) The limestones and serpentines in the Horton River basin, east of the Nandewar Mountains, outside the district which I have myself examined.

The *Igneous Rocks* comprise (a) granite, as rolled boulders in Maule's Creek.

(b) Akerite, occurring as laccolitic bosses and sills at the head of Bullawa Creek. Also ægirine-nepheline syenite, forming sills in the same region.

(c) Sills of syenite-porphyry and bostonite.

(d) Trachyte, phonolite and rhyolite, with all kinds of texture, from aphanitic and even-grained to coarse and porphyritic, and from compact to highly vesicular. These rocks occur as lava-flows or cappings, dykes and sills throughout the area extending from Deriah Mountain on the south to Couradda (Grattai) Mountain on the north, and from Noogera Creek on the east to the 1,000-feet contour on the west.

(e) Tuffs allied to the lavas in (d).

(f) Felspar porphyrites with labradorite phenocrysts exceeding in some case two inches in length and $\frac{3}{4}$-in. in thickness. This porphyrite occurs in sills associated with ægirine syenite sills which contain inclusions of fine-grained nepheline phonolite (*vide* Petrological Notes, N.12, N.11, and N.10).

(g) Porphyritic basalt with labradorite phenocrysts exceeding two inches in length.

(h) Lamprophyric porphyrite occurring as a sill at Dingo Creek. This rock has huge phenocrysts of rhombic pyroxene, some of which are from three to four inches long.

(i) Basalts capping the other lavas. Some of the basalts contain no olivine and resemble closely that from the Sandilands Ranges. The last erupted contain olivine.

(j) Tertiary (?) rhyolites and rhyolitic tuffs to the S.W. of the Nandewars between Maule's Creek and Boggabri. These rocks form cones and necks, and exist also to the west of Boggabri.

(k) Quartz porphyries and old rhyolites associated with tuffs and breccias at the head of Oakey Creek, Coolah, and between Maule's Creek and Barraba. These rocks appear to be of Carboniferous age.

Alluvials and Windblown Deposits.—(a) Black Soil Plains, as at Narrabri, occurring far and wide with interspersed sandy patches on the plains. The black soils are usually of river deposition, and are often of great depth. The alluvials and Tertiary deposits at Narrabri attain a thickness of over 1,000 feet.

(b) Poor sandy pine scrubs of the Pillaga type. The edge of Pillaga scrub is encountered on the Narrabri-Boggabri Road about 11-12 miles south of Narrabri (near Turrawan).

3. Geomorphology (including Physiography, Topography and Descriptive Geology).

To illustrate this part I have prepared two sketch maps, one of the Nandewar Mountains and Nandewar Range, including outlying parts which I have not visited (Plate xlvi.); and the other a map of the Nandewar Mountains themselves which I have personally investigated (Plate xlvii.).

The former is intended to bring out the following features :—

(a) The distinction between what is known as the Nandewar Range and the Nandewar Mountains proper. The Nandewar Range is an offshoot of the Moonbi Ranges, and connects the New England Mountains with the Nandewar Mountains proper. It forms a watershed between the Horton and Manilla Rivers. The Geological Survey Department's Map of New South Wales (compiled under the direction of Mr. Pittman, Government Geologist, 1893) shows that this range consists of Permo-Carboniferous rocks and older rocks of Carboniferous and Devonian age, such as serpentine, limestone, slate, &c., but where it merges into the Nandewar Mountains proper (which might appropriately be termed the Lindesay Group) these old rocks are capped with the lavas of the Tertiary trachyte and basalt series.

(b) The direction of flow of the rivers and creeks.

(c) The mountainous nature of the country between the Nandewar Mountains and New England.

(d) The geological formations of the country from which, in conjunction with the configuration, deductions may be drawn as to its geological history.

The second map shows the configuration and the geological formations of the Lindesay Group, from which deductions will be drawn in the section on Geomorphogeny.

The Nandewar Mountains as seen from afar (as from Narrabri or from the Warrumbungle Mountains peaks) form a dome-shaped mass. The highest point of the group is Mount Kaputar, about 5,000 feet high, and the Lindesay Tableland surrounding it is over 4,000 feet in average altitude, with many eminences on it approaching 5,000 feet. The Nandewar Mountains (Lindesay group) cover an elongated oval area, having its long axis running N.N.W.-S.S.E. The highest peaks are situated on this axis, from which spurs capped with smaller peaks run W.S.W. and E.N.E. The spurs are separated by deep, narrow, gorge-like valleys, with steep, often precipitous, walls on each side. The cliffs usually expose sandstone up to a certain height (about 2,000 feet), above which we find flows of trachyte. Both in a N.N.W. and in a S.S.E. direction from Mount Kaputar the axis gradually declines in altitude; so that, at the head of Bobbiwaa Creek it averages only about 2,500 feet; and at the head of Oakey Creek (Coolah Station), a branch of Maule's Creek, its height is 2,400 feet, though peaks of higher altitude are met with on the chain.

The Black Soil Plains surrounding the Nandewar Mountains resemble those already described for the Warrumbungles. They may be either with or without forest. The commonest trees on the forested black soil plains are box (*E. hemiphloia* var. *albens*, and *E. Woollsiana*), apple trees (*Angophora intermedia*), ironbark (*Eucalyptus crebra*), oaks (*Casuarina Cunninghamii* and *C. Cambagei*) along watercourses or plains of alluvial origin; and box (*E. hemiphloia* var. *albens*), with myall (*Acacia pendula*), ironbark (*E. melanophloia*), wattles (*Acacia*), when black soil is purely of volcanic origin as at Bobbiwaa Creek.

The Pilliga Scrub adjoining Narrabri at Turrawan answers to the description already given of other parts of the same area. It consists of a thick pine (*Callitris calcarata*) jungle with occasional ironbarks (*Eucalyptus sideroxylon*) and wattles interspersed, growing on deep white or yellow sand. The lower branches of the pines exhibit a remarkably even skyline, due to a process of natural pruning which is better illustrated here than at any other spot which I have seen in Australia. Patches of poor sandy country of the Pilliga type occur also between Maule's Creek and Boggabri. Here it is very undulating, capped with table-topped hills (mesas) of conglomerate and sandstone which are probably of Trias-Jura age. These mesas would, if their tops were continuous, form an inclined plane sloping away from the Nandewar Mountains. In this way, too, the mountains descend into the plain in a southerly direction. In the Parish of Namoi, County Darling, they run into the Namoi River and disappear. Around Boggabri and west of this township the country would be level but for the numerous volcanic knobs of rhyolite and rhyolitic tuff and breccia which are bestrewn over the plain, and rise above it to a height of 500 feet or more. These rhyolites probably are Tertiary eruptives, but may be older. At all events they intrude the sandstone (Permo-Carboniferous ?).

West of the Nandewars, around Narrabri, thence westwards in the direction of Walgett and northwards towards Moree, the country is almost perfectly flat, consisting of black soil plains and interspersed sandy patches of the Pilliga type. There are jutting out of the plains a few miles east of Narrabri several small hills composed of porphyritic basalt and basic tuff. To the north-west of the Nandewars, in the Parishes of Mellburra and Myall Hollow, there are a few hills, almost conical in shape, such as The Haystack and The Little Haystack. They, too, are basaltic. In the Counties of Murchison and Darling, east of the Nandewar group, the spurs of the latter are also, according to the Geological Survey Map, capped with basalt; and basaltic intrusions, and extrusions occur at intervals throughout the area lying between the Nandewar Mountains and New England. My own observations, as far as they go, show that volcanic rocks (trachytes and basalts) cap the ridges east of the Nandewar group.

Dykes of basalt have been noticed cutting the trachytic and phonolitic rocks in the Nandewar Mountains. This shows that here, as in the case of the Warrumbungles, the last eruptions were basic and extended over a wide area.

Bullawa Creek, from the petrologist's point of view, is by far the most interesting locality in the Nandewars (Fig.1). On the south side of the creek near Ritter's homestead numerous broken hills intervene between the lava-tableland (Ningadhun, Coryah, etc.) and the creek. In these, sandstone is usually the dominant formation to a height of about 2,250 feet, and a slight S.E. dip is generally observed. It seldom exceeds 5°. A bed of coarse conglomerate with abundant quartz and cherty pebbles is met with at an altitude of 1,900 feet. To the north of the creek no broken hills intervene; an abrupt razorback range forms the

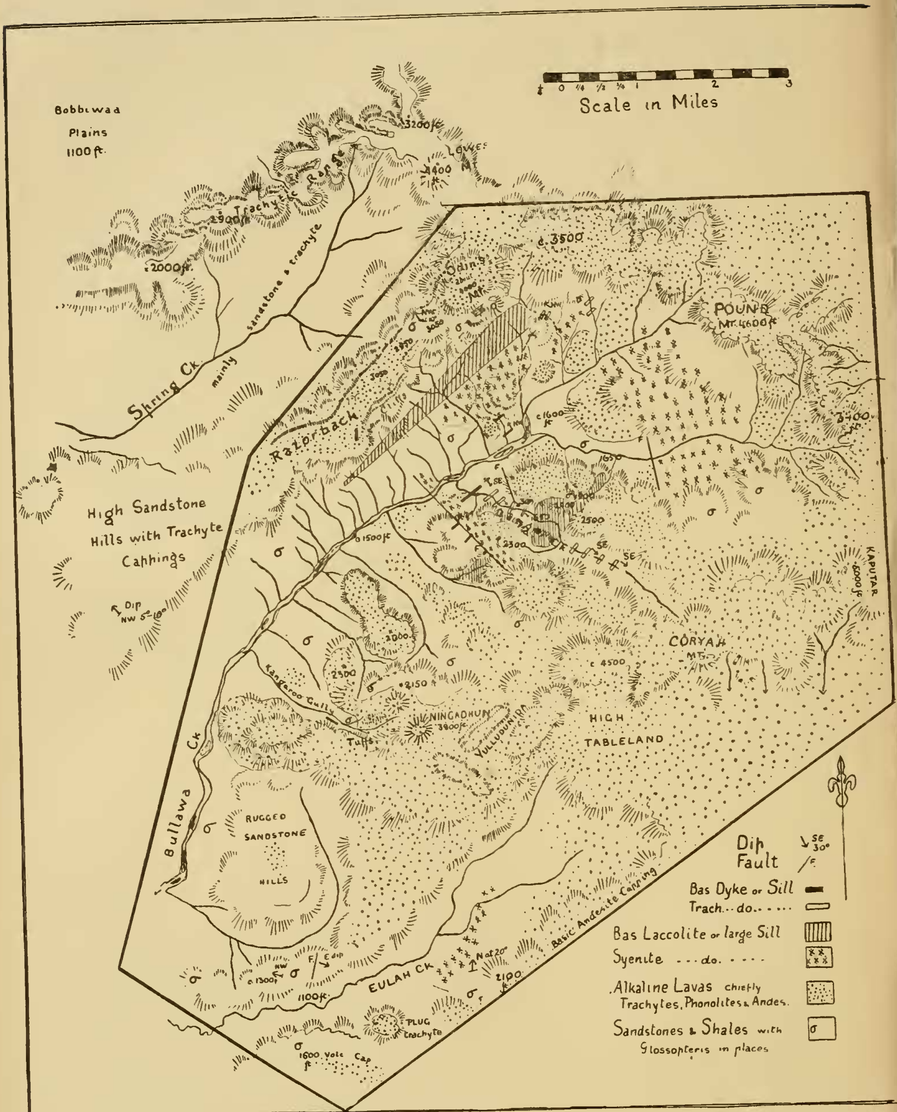

Fig. 1.—Geological Sketch Map of Bullawa Creek.

watershed between Bullawa Creek and Spring Creek. In this razorback the coarse conglomerate bed is met with at an altitude of 2,000-2,100 feet, about 200 feet higher than one mile south. This means a dip of 1 in 25 to the south, or of about 5° to the S.E.

Kangaroo Gully is interesting because of the occurrence there of a type of porphyritic basalt with phenocrysts of plagioclase up to two inches in length. The basalt penetrates sandstone and apparently also trachytic tuffs. It is similar to basalts found elsewhere in the Nandewars intruding and capping the trachytes, being alkaline and without olivine. Both in hand-specimen and under the microscope the Nandewar post-trachytic basalts resemble the Sandilands Ranges basalt. On the east side of Kangaroo Gully there is a high trachyte ridge commencing in the Sugarloaf, N.N.W. of Ningadhun. The trachyte of the ridge caps trachytic tuffs, which again overlie sandstone. The trachyte is therefore a flow which has infilled an old valley. On the western side of the gully the formation consists of tuffs and breccias. In the Triassic (?) sandstones north of Kangaroo Gully there are carbonaceous shales but no fossils. The dips are somewhat disturbed.

East of Kangaroo Gully occurs a sill-like or laccolitic mass of arfvedsonite trachyte porphyritic in anorthoclase. To the north this merges into an eruptive conical mass.

The ascent of Ningadhun from the N.N.W. is interesting, inasmuch as various kinds of alkaline volcanic rock are met with in well defined sheets as shown in Fig.2. Ningadhun rock itself is a plug left by the removal of surrounding tuffs. Behind Ningadhun on Yullundunida there is a slanting dyke-like razorback dipping sharply to the S.E. It appears to be a relic of a surface-flow from Ningadhun capping the tuffs now removed by denudation (Plate 4). About half-a-mile N.N.W. of Ningadhun there is a sugarloaf of arfvedsonite trachyte which represents a plug in a parasitic vent.

The sandstone beds north of Bullawa Creek have a slight N.W. dip. The S.E. dip so general on the other side of the creek is probably induced by a subsidence along a fault running E.N.E.-W.S.W. from Kaputar in the direction of Ningadhun, the plugs of Kaputar, Corrunbralborawah, Coryah, Ningadhun being situated on this line. The range north of Bullawa Creek,

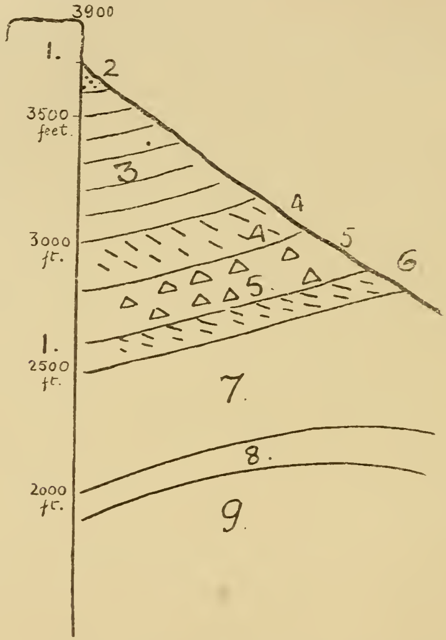

Fig.2.—Structure of Ningadhun Rock.
1, Silky Arfvedsonite trachyte; 2, Black trach. glass; 3, Coarsely porph. hypohyaline black trach.; 4 and 6, Red neph. phonolite; 5, Trach. breccia; 7, Common varieties of alk. trach.; 8, Tuffs; 9, Conglomerates and sandstones.

Ritter's Razorback, has trachytic rocks (tuffs, breccias and lavas) above a height of 2,200 feet. In places these rocks become andesitic, in others phonolitic. They frequently exhibit spheroidal weathering and onion-structure.

From the structure observed in the country on both sides of Bullawa Creek at Ritter's as described above (Figs.3, 4, 5) it

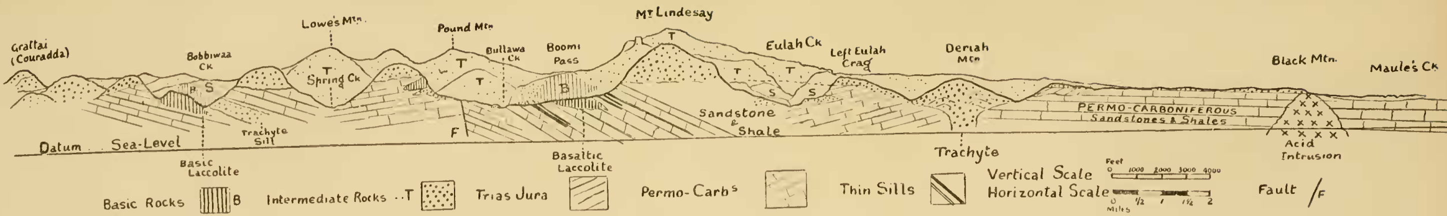

Fig. 3.—Section in a general N. and S. direction through the Nandewar Mountains.

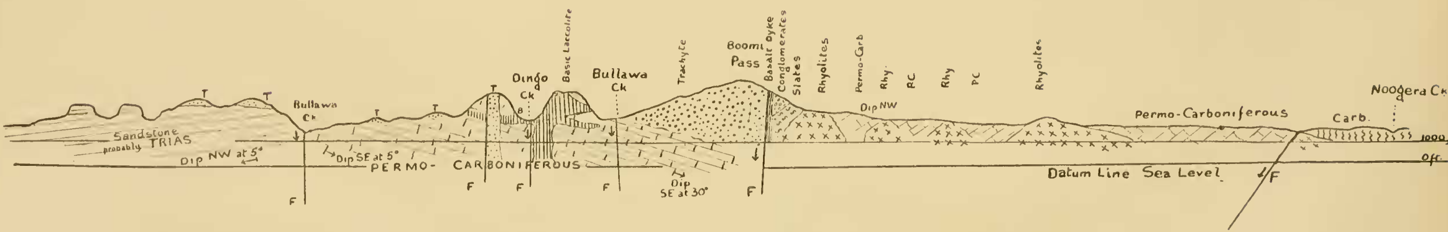

Fig. 4. Section in a general E. and W. direction through the Nandewar Mountains.

appears that the trachyte has flowed over an eroded surface and infilled the valleys. The present valleys, such as that of Bullawa Creek, represent the high ground before the period of the eruptions; the thin flows capping the sandstones here having soon become denuded away, erosion has rapidly carved out valleys in the softer sandstones and shales.

North by east to north-north-east from Ritter's farm The Razorback attains a height of 3,050 feet and is capped with vesicular amygdaloidal trachytes. Further eastward, about $\frac{3}{4}$ or $\frac{1}{2}$ a mile from Mount Odin, sandstones and conglomerates dipping N.W. at 5-10° cap the range at an altitude of from 2,950 to 3,050 feet (Fig.5). The change in formation makes an immediate change in the forest flora, pine (*Callitris calcarata* ?) and

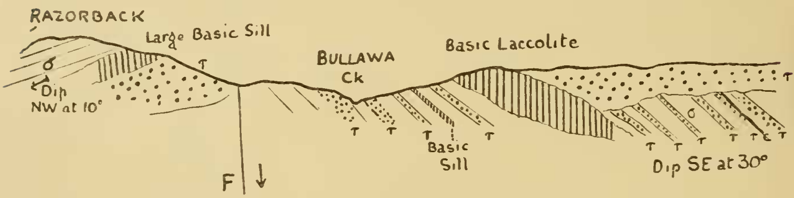

Fig.5.—Section across Bullawa Creek at Dawson's, in a general N. and S. direction. F, fault; τ, trachyte or bostonite; σ, sandstone.

oaks (*Casuarina Luehmanni* and *Cambagei*) replacing the box and gum. Smaller cappings (relics) of trachyte occur here too. On descending The Razorback, walking southwards towards the junction of Bullawa and Oakey Creeks, a large sill or dyke of basic rock is met with. The outcrop is 300 yards wide. Below this basic mass trachyte porphyry becomes the country rock, and represents a laccolitic offshoot of the Mt. Odin mass (Fig.5). Mt. Odin is precipitous on the northern, western, and southern flanks, and has a steep slope to the east towards the gap between Bullawa and Pound Creeks. The cliffs consist of sandstone beds alternating with trachyte or porphyry sills. My brother in proceeding up the creek called on my map Thor's Gully, observed numerous sills of trachyte and dolerite intruding sandstones, carbonaceous shales and conglomerates. The sills frequently locate waterfalls in the creeks.

The country between Mount Odin, Rocky Creek Gap, and Oakey Creek is very broken, consisting of dark green porphyry sills and trachyte porphyry sills intruding Permo-Carboniferous sandstones and shales with Glossopteris. Nearly all the hills have cappings of vesicular trachyte.

Further up Oakey Creek, about a mile above its junction with Bullawa Creek, massive syenite (akerite) is met with on both sides. This rock has a pepper-and-salt colour, and would make a beautiful building stone.

Some of the dark syenite-porphyry sills contain angular and rounded included masses of nepheline phonolite, which seem to be fragments of the already cooled magma torn off the walls of the lava-reservoir in the upward passage.

Oakey Creek contains pebbles of dark syenite-porphyry, grey (pepper-and-salt) syenite, red syenite, essexite, ægirine trachyte, ægirine phonolite, red trachyte, trachyte porphyries, basalt and basalt porphyrites; therefore all these rocks must occur in the area which it drains. Grey syenite (akerite) covers a large area of rugged country between Oakey Creek and Upper Bullawa Creek. The occurrence of pine higher up the range under Pound Mountain shows that the syenitic mass has a sandstone capping. Above the sandstone on Pound Mountain and the Nandewar Range in general there is a capping of vesicular volcanic rocks.

The upper part of the Bullawa Creek (that is above its junction with Oakey Creek) cuts through great igneous masses of trachyte and trachyte porphyry. Very little sandstone is seen in the area. Here and there a small remnant may be noticed high up on the mountain sides, and may be taken to represent either a floated-up portion of the country rock or remnant of a sill-capping which has not been resorbed.

South of Bullawa Creek we have a great tableland capped with the peaks Kaputar, Corrunbralborawah, Coryah and Ningadhun. This mass consists at the base of Permo-Carboniferous sedimentary rocks intruded by numerous sills and laccolites with a

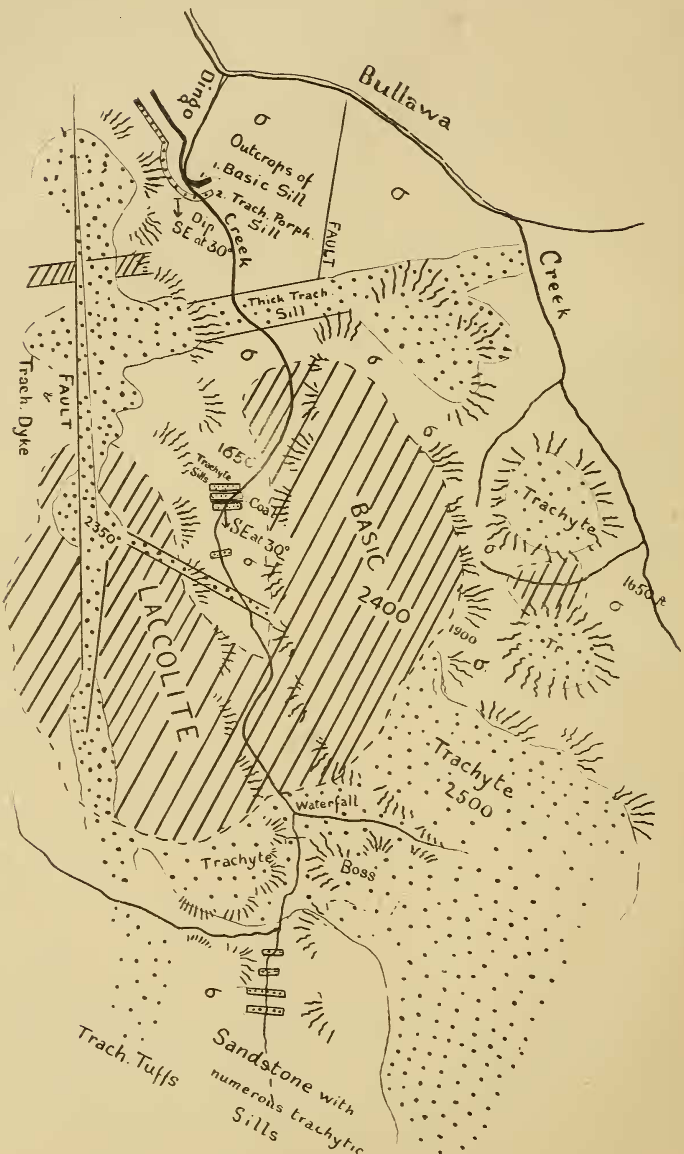

Fig. 6.—Geological Sketch Map of Dingo Creek.

covering of vesicular volcanic rocks. Bullawa Creek itself flows from its junction with Oakey Creek through sandstone and trachyte sills. Sandstone, shale, dolerite, trachyte, and many other rocks chiefly related to the trachyte family occur in the broken country between it and the tableland.

At Dingo Creek most interesting features were observed. Not far (about 250 yards) from its junction with Bullawa Creek there is a remarkable sill of lamprophyric porphyry intruded along a coal seam (S_1). The dip of the strata is S.E. at 25°. Below and above the sill there are Glossopteris and Noeggerathiopsis shales and cherts indurated by the intrusion.

About 500 yards further up the creek we meet with the boundary of a great laccolite of basic porphyrite intruded by occasional trachyte dykes. As I have seen sandstone both overlying and underlying this rock, I have no doubt it is a laccolite. Sandstone dips are somewhat disturbed near its edges. Further up the creek the basic rock is seen sometimes only on the east bank, sometimes on both banks, and the creek has largely carved its way along the western edge of the mass. On the west bank of the creek, cliffs of sandstone with coal seams and Glossopteris shales are common. They dip S.E. at 25-30° and contain interlaminated sills of trachyte porphyry and bostonite, which generally have penetrated along a coal seam. The hills west of Dingo Creek are capped with trachyte, but those on the east side for some distance consist chiefly of dolerite, with trachyte cappings overlying it in places, a fact which proves that denudation had removed the sandstone covering of the basic laccolite before the trachytic rocks were poured out. The dolerite is of various degrees of crystallinity, some very coarse-grained, some, especially near the edges of the mass, fine-grained.

The ridge between Dingo Creek and the creek west of it owes its existence to a broad trachyte dyke running S.E.-N.W., from which many sills and dykes at right angles to it and flows capping the hills are derived. The basic laccolite has a maximum thickness of about 700 feet (Fig.4).

On proceeding higher up the creek, sandstones, shales and interlaminated sills repeat themselves, and the hills on both sides have lava-cappings.

Boomi Creek.—From Bullawa Creek I made an excursion across the mountains to Boomi Creek. The crest of Boomi Gap has an altitude of about 3,500 feet. South of it lies Kaputar (5,000 feet), north of it Pound Mountain (4,500 feet). In ascending the pass from the west one encounters practically only trachyte. However, on descending to Boomi Creek one crosses a basaltic dyke, running N. and S., at a height of 3,000 feet; at 2,900 feet there is an outcrop of greenish slaty rock; at 2,800 feet an outcrop of coarse conglomerates dipping north. These rocks are probably Permo-Carboniferous, perhaps Carboniferous. Lower down rhyolitic and andesitic tuffs and quartz porphyries are met with as well as conglomerates with rhyolite pebbles. These volcanic rocks and conglomerates are lithologically the same as those occurring at Laird's on Maule's Creek, Horse-Arm Creek and Black Mountain south of the group. Below the 3,000-feet level the Boomi Creek country loses the wild ruggedness characteristic of the Bullawa Creek side, consisting of more gently-sloping, wooded and grassy spurs well adapted for grazing. The change in scenery is due to the change in formation, Lower Permo-Carboniferous or Carboniferous rocks being here predominant, and the barren trachytes, Upper Coal Measure and Triassic sandstones being seldom seen. In Boomi Creek there are numerous boulders of coarsely porphyritic basalt with gigantic felspar phenocrysts similar to that which caps the intermediate rocks round Deriah and intrudes them in Kangaroo Gully. This rock is probably derived from Kaputar.

Eulah Creek.—This creek rises in the Lindesay Tableland and flows parallel to Bullawa Creek into the Namoi. The country in which its two branches head is like that at the head of Bullawa Creek, consisting of sills of intermediate rock intruding Permo-Carboniferous or Trias-Jura sandstones, which rise abruptly on either side to form a tableland capped with lava. The creek, like Bullawa Creek, flows in a gorge-like valley, which at

Dunmore's place, where I camped (altitude 1,150 feet), has sandstone cliffs 400 feet high on either side. Higher up the creek cliffs of igneous rock are frequently seen. Ascending the tableland south of Dunmore's the sandstone formation was seen to persist to a height of 1,600 feet, where dark, fine-grained cappings of ægirine-trachyte or andesite commenced. Much of it is quite scoriaceous. The sandstone north of the creek has a gentle dip to the N.W. at Dunmore's, changing to N.E. as one proceeds upstream. South of the creek it has a gentle westerly dip.

Between Dunmore's and Deriah Mountain coarsely porphyritic basalts without olivine and andesites cap the trachyte in various places on the tableland at a height of 1,650-1,700 feet. The forest vegetation improves at this level, consisting of box (*Eucalyptus albens*), cedar (—— ?), kurrajong (*Sterculia diversifolia*), watergum (*E. rostrata*), and wattles. A basaltic crater occurs a couple of miles west of Deriah. Boxtree Gully heads near it (Fig.8).

Deriah Creek heads near Deriah Mountain, the structure of which is represented in Fig.7.

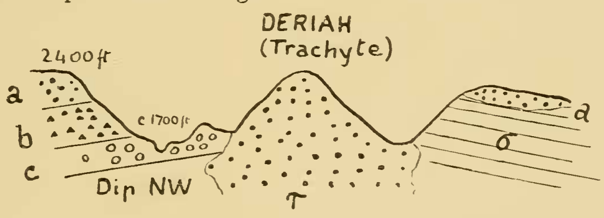

Fig.7.—Section, in a general E. and W. direction, at Deriah. a, andesitic rock; b, trachyte breccia; c, vesicular trachy-andesite; τ, arfvedsonite trachyte; σ, sandstone (Triassic ?).

The Deriah Mountain trachyte is *older* than the fine-grained blue ægirine-nepheline phonolite and phonolitic trachyte which occur under the basalt of the surrounding hills (Figs.7 and 8).

At Left Eulah Crag on Eulah Creek, north of Deriah, a large sill of even-grained arfvedsonite-trachyte intrudes the sandstone and forms a bold cliff. In the area lying between Deriah and Eulah

Crags the hills are commonly capped with a coarse andesitic or trachytic breccia.

It is probable that on the tableland between Eulah and Bullawa Creeks, basalt caps the alkaline intermediate rocks. The curious, long dykes surmounting the plateau are evidence of fissure-eruptions which first gave rise to tuffs, and later on to lavas, the flows of which have been undermined by the subsequent weathering away of the underlying tuff-beds.

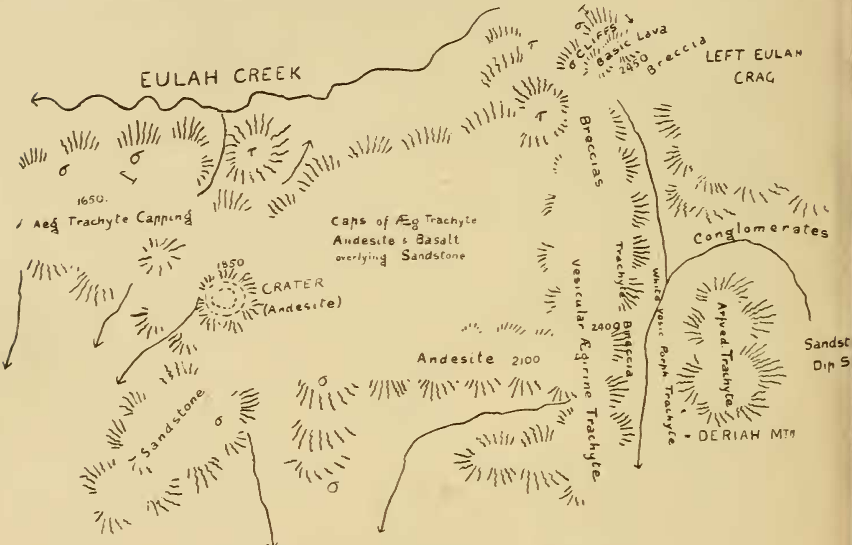

Fig. 8.—Plan of Country round Mt. Deriah.

Bobbiwaa Creek is separated from Spring Creek by a razorback spur similar to that which separates Spring Creek and Bullawa Creek; but, unlike the other creeks dealt with, it flows in a broad plain-like valley, three or four miles wide as far up as Dripping Rock, and a few miles lower down it leaves the mountain altogether. The hills facing Bobbiwaa Creek in its upper reaches are not cliffs, hence the valley is nowhere cañon-like. In fact, this creek forms a natural gap between the volcanic masses north and south of it. The country between Bobbiwaa

Creek and Grattai (Couradda) is as rugged as that of Bullawa Creek, but the creek valley itself is a plain. Its level nature is apparently due to the fact that it was already a deep, broad valley when the eruptions took place, and though lavas entered it both north and south they by no means sufficed to fill it. This conclusion is borne out by the existence of volcanic trachytes at the level of the creek below Dripping Rock. The range between Rocky Creek and Bobbiwaa Creek has isolated trachyte cappings which are flows from dykes, but where the road crosses it there is no such cap (altitude 2,200 feet). It has been removed by denudation. The strata at the pass consist of Permo-Carboniferous sandstones and shales with a coal seam about 6 feet thick outcropping on the top. The dip appears to be S.E. at angles not exceeding 10°. A great laccolitic mass of basic rock similar to that at Dingo Creek and exhibiting similar variations intrudes the Permo-Carboniferous strata at the head of Bobbiwaa Creek, and attains a thickness of 400 feet. The numerous mountains (Dripping Rock, Grattai, etc.) lying north of Upper Bobbiwaa Creek consist partly of sandstones with basic sills and partly of sandstone with trachyte sills and flows. Some of the peaks are wholly composed of trachyte. The cappings of columnar trachyte all slope to the N.W., indicating an original slope in that direction before the outpourings, or that the flows came from the S.E., near the head of Bobbiwaa Creek. Across the range in the Rocky Creek valley the country is mountainous but not rugged. It consists essentially of Permo-Carboniferous rocks with basic sills and later trachyte dykes.

Maule's Creek.—The country surrounding this creek must also be dealt with separately. To Maule's Creek I proceeded from Tarriaro and struck the creek a few miles below its junction with Horse-Arm Creek. Between Tarriaro and this junction the country is sandy, very gently undulating, on the whole poor, and traversed by a number of shallow gullies heading in the mountains to the north-east; the gullies are devoid of water except when torrential rains occur and send the water down in sheets. Many of these watercourses are purely relics from a time when the mountains stood higher and had a greater rainfall. Abrupt sandstone cliffs facing the S.W., and situated where Bibbla Creek and Deriah Creek leave the mountains, are seen from Tarriaro. This portion of the country is marked on the Government Geological Map of New South Wales as Triassic.

Black Mountain is shown on the Government Geological Map as consisting of acid igneous rock. On my map (Plate xlvii.) I have taken this for granted, although in ascending the mountain from the south I saw only sandstones and conglomerates with a basalt sheet on top. I saw, however, some loose fragments of a dioritic rock, which must be derived from an outcrop near by.

All the mountains between Black Mountain and Deriah present the same features, and consist probably of sandstones, conglomerates and shales of Upper Coal Measure and Trias-Jura formations with basalt sheets on top.

About 1½ miles south of Maule's Creek, near Laird's place (Berrioye Station); there is a ridge of hills running N.W.-S.E. (Long Plain Mountain). It consists of conglomerate made up chiefly of rhyolite pebbles. Mr. Laird has found fossil leaves in ironstones associated with these conglomerates, and his description of them answers to that of Glossopteris, so that the conglomerate must be Permo-Carboniferous, and the rhyolites from which the pebbles in them are derived must therefore be older. The pebbles of Maule's Creek consist of rhyolite chiefly, with a little granite, basalt and trachyte. In Horse-Arm Creek the pebbles are mostly of basalt, sandstone and trachyte.

The average height of the hills (mesas) north and south of Maule's Creek in this region (*i.e.*, between Horse-Arm Creek, Pinnacle Creek, and Stony Creek, Berrioye Station) is 1,400 feet, increasing towards the north and diminishing towards the S.W. At Buron Creek conglomerates of Permo-Carboniferous age are observed dipping N.W. On the Coolah side of this creek the valley of Maule's Creek becomes a gorge with high hills fronted with cliffs and escarpments on both sides, while down stream Maule's Creek flows in a broad valley—a perfect plain continuous with the Tarriaro and Narrabri plains—and delimited on the north and south by mesas several miles removed from the creek. This Maule's Creek plain marks an area of undoubted Permo-Carboniferous age. It is well-grassed and timbered, box trees, an indication of good soil, being abundant. The mesas north and south of it are probably chiefly of Upper Permo-Carboniferous age, but of Trias-Jura age in places, especially between Black Mountain and Deriah. The sandstones of the mesas are composed chiefly of quartz sand and the conglomerates of quartz pebbles, and the vegetation is very poor. The Lower Permo-Carboniferous sandstones and conglomerates give a much better soil, containing much felspar of rhyolitic origin.

In the gorge above its junction with Buron Creek, Maule's Creek has cut through a series of conglomerates composed of rhyolite pebbles like those of Berrioye, but having, nevertheless, a totally different appearance—being, in fact, boulder beds, containing boulders up to two feet in diameter. They are chiefly tilted in places and exceed 1,000 feet in thickness. On the Government Geological Map this area is put down as Carboniferous, an estimate which appears to me to be correct. Mount Byar and Mount Coolah are composed of massive conglomerates with interbedded sheets of tuff and rhyolite (quartz porphyry), the pebbles of the conglomerate being identical in nature with the interbedded sheets. Above Coolah Station on Maule's Creek and its branch, Oakey Creek, similar rocks occur, but near Waterloo Pinnacle cherts and slates are met with in the hill-slopes. They are highly metamorphic, and sills or dykes of orthoclase quartz porphyry intrude them. They are probably Devonian, and the whole series here seems to dip E. at 20°.

The rocks of Byar and Coolah Mountains on the other hand have a N.W. dip at angles up to 20°. The Pinnacles, a couple of peaks north of Coolah, are remarkable for being as rugged and precipitous as trachyte plugs. I went to them expecting to find them composed of trachyte, but to my astonishment they consisted of Carboniferous conglomerate similar to Byar Mountain, dipping N.W. at 20°. The dips around Coolah Station are not very reliable, at any rate the time I spent in the vicinity was not sufficient to work them out properly. The confusion is due to (a) the extraordinary conditions under which the conglomerates were formed, (b) subsequent quartz porphyry intrusions, (c) mountain-building movements. However, speaking generally, the rocks S.S.E. of Upper Maule's Creek and its branch, Oakey Creek, dip in an easterly direction, whilst those west of them dip N.W., so that these two creeks occupy the position of the crest of an anticline, or perhaps the line of junction of Devonian and Carboniferous rocks. The latter hypothesis is the less probable, as the rocks on both sides of the line are very similar.

Between Coolah Station and Boggabri the country is studded with mesas and mesa-like ridges of barren sandstone. Near Boggabri buttes of rhyolitic lava and tuff become abundant. To the south of Boggabri, between it and Gunnedah, the formation is Permo-Carboniferous sandstone capped with alluvial in places. West of Boggabri lies the Pilliga Scrub, in Upper Coal Measure country, composed of very barren sandstones. Between Narrabri and Boggabri the same formations occur. On the road, about half-way between the towns, some large basaltic sheets are crossed; further north, at Tipperina, the road passes through an edge of the Pilliga Scrub (sand).

Seen from Maule's Creek plain or from Boggabri, the Nandewar Range south of Coolah presents the remarkable appearance of being capped with peaks which all have a steep slope to the south and a gentle slope to the north. The only explanation which I can suggest to account for the phenomenon is that there may have been step-faulting with the downthrow of the southern wall in each case.

The Manilla Range west of Boggabri I did not find time to visit, but judging by its rugged appearance it is probably composed of volcanic rocks, in all probability rhyolite.

4. Geomorphogeny.

(a) *General Discussion.*—From the foregoing description we see that the Nandewars, like the Warrumbungles, may be looked upon as a conoplain, which is composed of sedimentary strata intruded by sills and capped with volcanic rocks, and has been dissected by semi-arid agencies. The gorge-like valleys in the mountains with vertically retreating cliffs, the steep shingle-covered slopes, the want of definiteness in the watercourses when they leave the mountains, and many other features are characteristic of an arid cycle. This country did not have much appearance of aridity at the time of my investigations. On the contrary, it was covered with waving fields of wheat and high grass, and rains occurred almost daily. However, it must be borne in mind that any area in which the rain falls principally at certain times in the year, the wet season, and then falls in torrents, whilst other periods, the dry seasons, extend over most of the year, and in which prolonged droughts occur, has the arid cycle characteristics and is classed with arid regions. Round the Nandewars on the west and south we have mesas of sandstone which show a N.W. dip. These are probably of Trias-Jura age, but may be Upper Permo-Carboniferous.

Mount Kaputar is the apex of the Nandewar Mountain mass. The mountain group is not round but oval with the long axis N.N.W.-S.S.E. It is composed of two definite masses, one north and one south of Bobbiwaa Creek. The highest peaks of the northern do not greatly exceed 3,000 feet in altitude. They are Dripping Creek (or Castle-Top), Grattai (Couradda), Terrergee, and others. The peaks of the southern mass are much higher, many exceeding 4,500 feet; Kaputar, the highest, is 5,000 feet high. Bullawa Creek divides the southern mass into two divisions, the northern of which is very dissected, whilst the southern is a compact tableland. On the large tableland are the curious tower-shaped peaks of Corrunbralborawah, Ningadhun, etc., and the long razorback dykes, like Yullundunida, which indicate late intrusions of hard trachyte into softer tuffs or andesitic lavas that have more easily been denuded away. Remnants of crater-rings are abundant but not very definite. One fairly definite basaltic crater has been noticed south of Eulah Creek. Ningadhun is probably a plug injected into the neck of a volcano,* and the high conical mass north of it is a similar plug in a parasitic vent. In American phraseology, these plugs may be termed buttes.

The wide Black Soil Plains expanses of Bobbiwaa Creek and Maule's Creek, with so gentle a slope towards the general plains of Narrabri and Tarriaro that the country might be said to be practically level, show clearly that a previous wet cycle cut gorges in the elevated conoplain and carved wide valleys. Then followed an arid cycle with disintegrated drainage, the result of which was the filling of the valleys with the detritus; lastly there has been a return of slightly moister conditions, hence there is a tendency for the drainage to become integrated again and for the creeks to become rejuvenated. The formation of black soil plains and the subsequent rejuvenation of the streams may bear a relation to the formation of a lake in the north-western districts of New South Wales and its subsequent drainage through its waters finding an exit by way of the Murray River. The arid period probably followed this last event.

(b) *Geological History.*—The geological history might be summed up as follows:—In the Carboniferous period the area of the Nandewar Mountains and the country to the north-west of them consisted of dry land on which Silurian, Devonian and older rocks were undergoing corrasion and denudation. The detritus was carried eastwards and southwards to a Carboniferous sea of which good evidence is seen at Maule's Creek. This sea extended westwards over the Barraba, Cobbadah, and Bingera districts as far as New England. Volcanic eruptions of an acid nature took place at the time—often in the sea or along the coast-line, so that on the shore huge pebbles and boulders of rhyolite accumulated. Eruptions took place at frequent intervals, so that we find tuffy sandstones and conglomerates, boulder beds with a volcanic ash matrix, and occasionally lavas all inter-bedded with one another. These eruptions were accompanied

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* *Cp.* 'Geology of The East Moreton,' etc., These Proceedings, 1906, p.97.

and followed by the elevation of the marine area and the subsidence of the continental area westwards. Hence a considerable thickness of coarse conglomerates and boulder-bearing tuffs was formed. At Coolah Station they are over 1,000 feet thick. By the middle of the Permo-Carboniferous period the continental area had been depressed beneath sea-level and sediments began to accumulate there. They are universally of shallow-water, estuarine, and lacustrine origin, comprising sandstone, conglomerate, grit, Glossopteris shales and coal-seams. No marine fossils have been observed. The grits and sandstones were derived from the denudation of rhyolites and granites which were now undergoing weathering in the elevated regions to the north and east. There is a distinct unconformity between Permo-Carboniferous and Carboniferous beds at Maule's Creek. Those of Carboniferous age are more highly folded, often faulted, and have interbedded igneous rocks derived from contemporaneous volcanic action.

Trias-Jura sedimentation followed Permo-Carboniferous. Subsequent to this came the folding of the deposits, from the S.S.W., against the New England massive. Elevation took place. The uplift was probably contemporaneous with one in New England which preceded the Mole Cycle.* The uplift in the Nandewar region probably gave rise to a gentle fold running N.N.W.-S.S.E. locating the mountain axis. Laccolitic injections of basic rock (olivine dolerite, etc.) took place at the same time (probably Cretaceous). Base-levelling to the level of the western Cretaceous sea left a peneplain with a gentle slope to the west; its level in the Nandewar Mountains is marked by the flat-topped sandstone mesas averaging about 1,400 feet in altitude.

Further earth-movements of late Cretaceous or more probably of early Tertiary age, coincident with the Tertiary elevation of New England (introducing the Stannifer Cycle) in which Bingera and Barraba districts shared, seem to have given rise to a fault.

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* Andrews, 'Tertiary History of New England,' Records Geol. Surv. N. S. Wales, Vol. vii.

The western side was thrown down, so that lavas flowing from the main fissure poured chiefly westwards. The eruptive and intrusive (sill) materials from the main fissure and from intersecting secondary cracks gave rise to the lava dome.

Mr. Andrews has shown that the New England and adjoining areas underwent rapid elevation in the late Cretaceous and early Tertiary periods, and were at the same time suffering rapid denudation. At the same time the west of New South Wales was being loaded with sediments. The Nandewars lie on the border of these two zones. Probably strain caused by the differential movement on either side was an important cause of faulting.

The downthrow of the western and elevation of the eastern side of the fault have tended to preserve relics of Triassic and upper Permo-Carboniferous rocks west of the fault and to expose Carboniferous and Devonian rocks east of it.

Tertiary denudation has dissected the conoplain established at the end of the volcanic cycle, and the products of erosion have been deposited (aggradation) in a depression formed by faulting, so that a thickness of over a thousand feet of soft Tertiary rock and alluvium has been formed at Narrabri. The Namoi River has also helped to aggrade the depression.

(c) *Volcanic Action.*—The order of eruption, judging by field observations, seems to have been as follows:—

(1) Pre-Tertiary, probably early Cretaceous, basic intrusions in Permo-Carboniferous strata.

(2) Tertiary: (*a*) Sill-like and laccolitic intrusions of syenite accompanied by flows of phonolite, trachyte, and allied alkaline lavas. (*b*) Alkaline andesites and more porphyry sills. (*c*) Basic porphyrite dykes and basalt flows.

The basaltic eruptions probably lasted well into the Miocene and Pliocene periods. The volcanic period was an era of great uplifts caused by the injection of sills and laccolites. The uplifts led to changes of dip in the sedimentary rocks and disturbed the uniformity of the M[illegible]ole level in the region, considerably increasing it towards the centre of the group.

Considering all the igneous rocks of the Nandewar Mountains, we have to add the rhyolites and quartz-porphyries lying south-west and west of the group. These were of Devonian and Carboniferous age, and closely resemble lithologically the Snowy River porphyries.

The relative ages of the various igneous rocks have been determined as follows :—

(1) Rhyolitic tuffs occur in the Carboniferous sediments, and rhyolitic pebbles occur in Permo-Carboniferous sandstone conglomerates. The rhyolite therefore antedates the Permo-Carboniferous.

(2) The basic laccolites intrude the Permo-Carboniferous, but are cut by trachyte dykes. They have formed at a considerable depth, hence before the dissection of the Mole peneplain. They must therefore be Triassic or early Cretaceous; for reasons advanced above, probably the latter. They may even be of the same age as the basic granites and intermediate rocks of New England.

(3) The trachytes intrude Permo-Carboniferous rocks and the later basic laccolites. Lithologically they are identical with the trachytes of the Warrumbungle Mountains and Glass House Mountains. In the absence of evidence to the contrary and in the presence of indirect evidence (drawn from plateau-erosion) in favour of the supposition, the same age, namely Eocene, must be assigned. They may be divided into two series :—

(1) Light grey trachytes, arfvedsonite trachytes, and rhyolitic trachytes, and syenite of a pepper-and-salt colour in sills and laccolites.

(2) Dark green ægirine trachytes (phonolitic) and sills of ægirine-augite syenite and of alkaline plagioclase porphyrites often containing fine-grained inclusions of phonolite of allied composition.

The second series is later than the first.

(3) The andesites form a connecting link between the ægirine trachytes and the basalts and grade into both. Many of the andesites are alkaline allied to phonolites.

(4) Basaltic eruptions came last, and the lavas are so rich in phenocrysts of an extraordinary size that cooling must have proceeded for some time at a depth. This phenomenon is also observed in the intermediate lavas (*cp.* the labradorite porphyrite, N.12).

Postbasaltic denudation has succeeded in carving the gorge-like valleys and in exposing volcanic plugs and dykes on the tableland, in removing crater-rings and in dissecting the semi-igneous mass. The original continuity of the tops of the spurs is shown by the volcanic rocks capping sandstones at the same level on either side of each valley at a height of many hundred or even 1,000 feet, and by the cappings of igneous rock on isolated sandstone mesas.

The irregularity of the lava-level in many places points to another significant feature, namely, that the area over which the lava flowed (the Mole peneplain ?) was at the time considerably dissected. Absence of marine fossils shows that it was land at the time of the eruptions.

It should be here again mentioned that around Boggabri there are numerous rhyolitic pinnacles which are probably of Tertiary age, contemporaneous with the Nandewar rhyolitic trachytes. They may, however, be older.

In the Pilliga Scrub, between Boggabri and the Warrumbungle Mountains, there are numerous conical peaks of andesite, probably of the same age. These igneous rocks serve to connect up the two volcanic regions, and show that the fractures in early Tertiary time roughly followed the border of the great Triassic basin.

(d) *Stream-Development.*—The nature of the Namoi River has already been discussed in my paper on the Warrumbungle Mountains. All the creeks rising in the Nandewar Mountains have their courses determined by the original slope of the conoplain, and are hence consequent streams. The evidence which they afford of a previous wet and a later arid cycle has already been discussed.

(e) *Present Changes.*—A recent rejuvenation is noticeable in some streams like Maule's Creek. This appears to be due to a gradual disappearance of arid conditions.

Volcanic activity has been long extinct, and there is no likelihood of its recurrence for many periods. The mountains are being base-levelled to the level of the western plains by the slow process of arid erosion. It is worthy of mention that, in addition to the other evidences of arid erosion already enumerated, many peaks in the vicinity of Dripping Rock, near Bobbiwaa Creek, display a very marked serrate topography. This characteristic I have not noticed elsewhere, and it is very striking.

5. Springs and Artesian Water.

Like the Warrumbungles, the Nandewar Mountains have many springs at high altitudes. Most of the important mountain springs flowed without intermission throughout the great drought, 1896-1902, when the creeks were all dry. Mr. Ritter told me of one spring near Pound Mountain which increased in strength during the drought to such an extent that the water rose in a fountain-like jet as thick as a man's arm.

The creeks dwindle enormously in size on reaching the plains west of the Nandewars. The reason of this phenomenon is that the water is absorbed by the great thickness of sandy alluvials which flank the Namoi for miles on either side.

Though many mesas south and south-west of the Nandewars are probably referable to the Trias-Jura, the sandstones underlying the alluvials of the plains in this quarter are mainly Permo-Carboniferous, hence the area is non-artesian. Some miles north of Narrabri, however, that is north-west of the Nandewars, there are sandstones which may belong to the Triassic intake beds of the artesian system.

6. Minerals of Economic Value.

The Nandewar Mountains, like the Warrumbungles, abound in veins of "potch" (poor opal) which occasionally contain specks of precious opal. The indications of precious opal are, however, as far as I have seen, not so good in this area as in the Warrumbungles.

Beautiful veins of chalcedony and agate abound, especially in connection with vesicular volcanic rocks.

Small diamonds have been obtained at the Alpha Mine near Bullawa Creek in gravel near a basalt dyke. It is possible that the basalt may have been the matrix, having absorbed the carbon from underlying coal seams. Rocks like the Enstatite-peridotite-lamprophyre (N.18, p.884) which are extremely basic, very rich in iron and magnesia, and intruded along coal seams, might easily absorb carbon and liberate it again in the form of diamond on cooling.

Coal seams have been observed in many places. In the area abounding in sills, such as around Bullawa and Eulah Creeks, the coal seams have in most cases been destroyed. On the summit of the divide between Rocky Creek and Bobbiwaa Creek there is, as already mentioned, a seam of good coal about 6 feet thick. No doubt in time to come many valuable coal seams will be found and worked in the area surrounding the mountains.

I have not noticed any diatomaceous earth deposits in the portions of the Nandewar Mountains which I investigated, but diatomaceous earths have been recorded from the vicinity of Barraba, south-east of the mountains, by Mr. E. F. Pittman.*

Other Alkaline Areas.

From the foregoing notes it is apparent that the two great volcanic areas of the Nandewar and Warrumbungle Mountains consist mainly of alkaline igneous rock varying greatly in basicity. Between them there are scattered masses of rhyolitic, phonolitic, and andesitic rock which form a chain connecting the two areas.

Similar scattered pinnacles and cones occur at intervals between the south-west corner of the Warrumbungles and Dubbo. This area is referred to the Upper Coal Measures on the Geological Survey Map, but on closer investigation much of it will probably

* Ann. Rept. Dept. Mines, 1881, pp.142-143. By authority, Sydney 1882.

be found to be Trias-Jura. In the first place, most of the sandstone between the Castlereagh River and the Warrumbungles has the appearance of being Triassic. The range lying between the Castlereagh and the Talbragar Rivers is probably also Triassic, the valleys only belonging to the Coal Measures.

Around Dubbo, to which I drove from Coonabarabran viâ Mundooran and Cobborah, there are Triassic rocks containing good imprints of *Thinnfeldia odontopteroides*: the best fossils were obtained at a well about 2 miles S.S.W. of Dubbo on the Peak Hill road. Further down, about 5 or 6 miles S.S.W. of Dubbo and about halfway between the Peak Hill and Obley roads, I examined some hills locally known as the Gibraltar Rocks. These consist of a grey, pepper-and-salt-coloured sanidine trachyte containing magnetite, arfvedsonite, and ægirine. It intrudes Triassic sandstone and the adjoining quartz-porphyries.

The occurrence of trachytes near Dubbo was first noted in 1905 by Mr. J. Murton, Geological Surveyor. Mr. W. S. Card has kindly supplied me with a specimen of the arfvedsonite trachyte found by Mr. Murton in the Parish of Dungarry near Dubbo. Its chemical analysis (by Mr. B. White) is quoted in my paper on the Warrumbungle Mountains.

Mr. Staff-Surveyor Thomas, of Dubbo, informs me that there are other knobs of trachyte at Minore, N.N.W. of Dubbo. Others occur S.E. of the Gibraltar group; probably therefore there is a string of these alkaline trachyte knobs connecting up the Warrumbungles and the Canoblas.

Mr. Card has lately received other interesting specimens from Mr. Murton, including specimens of nepheline syenite, nepheline phonolite.*

The Barrigan mass of tinguaite, referred to in Carne's 'Monograph on the Torbanite of New South Wales,' (Mem. Geol. Surv. N.S.Wales) though of a similar age to the alkaline rocks above dealt with, does not lie on the same curve. The masses dealt with lie

* "Miaskose," see 'Petrological and Mineralogical Notes,' No.10. Records Geol. Surv. N. S. Wales, Vol.viii.

on a line which runs S.W. from the Nandewars to the Warrumbungles, thence S.S.W. to Dubbo and Minore, thence S.E. to the Canoblas, and continues in the same direction to Mittagong, with outlying extrusions of a dark green variety as far west as Goulburn. It is likely that other alkaline trachytes and allied lavas will be met with between Barrigan and the Nandewars, and between Barrigan and Mittagong. If so, the belt of alkaline lavas forms a loop round the Gunnedah basin of Upper Coal Measure strata. The significance of this matter I propose to discuss more fully in a later paper.

It is also interesting to note that some considerable masses of fine limonite, iron ore, occur on Doyle's farm near Gibraltar close to Dubbo. On the Coonabarabran-Cobborah road, not far from Mundooran, some of the sandstones are so indurated with iron, in the form of hæmatite, that they could be smelted for iron. I have already mentioned that valuable deposits of a similar nature occur round the Warrumbungle Mountains. There is no doubt that in time all these districts will be worked for iron.

The origin or source of the iron I have not investigated, but as it occurs most frequently in the vicinity of igneous rocks it may have been derived from them by leaching, like the iron ores similarly situated near Mittagong.*

B. Petrology.

The rocks of the Nandewar Mountains may be divided into A. *The Volcanic Series*, consisting of :—

- (a) Ali-rhyolites (alkaline rhyolites), including comendite and quartz pantellarite.
- (b) Ali-trachytes (alkaline trachytes), including soda-trachyte, pantellarite, &c.
- (c) Phonolites.
- (d) Alkaline andesites.
- (e) Alkaline basalts.
- (f) Calcic rhyolites and basalts.

* Taylor, T. Griffith, and Mawson, D., 'The Geology of Mittagong,' Journ. Proc. Roy. Soc. New South Wales, Vol. xxxvii.

Of these subdivisions the first two have very many minerals in common, and show other points of similarity. The next three divisions are also closely related to one another, numerous intermediate forms linking them. They are also related to (a) and (b). The last subdivision has no relationship at ali to the others.

B. *The Hypabyssal Series*, consisting of :—

(a) Ali-syenite-porphyries (alkaline syenite-porphyries), including syenite-porphyry, ceratophyre, bostonite, sölvsbergite, grorudite.

(b) Felspathoid rocks such as pulaskite-porphyry.

(c) Augite-porphyrites and teschenites.

(d) Bronzite-peridote-porphyrites (monchiquitic lamprophyre).

Subdivisions (a) and (b) of the Hypabyssal Series are closely related to one another, but not to (c) and (d). The intrusions of the last two rock-types are later than Permo-Carboniferous, and probably also Post-Triassic, but not Post-Cretaceous, for they are nowhere seen interbedded with or capping sediments of Cretaceous age; but we find them underlying the fluviatile deposits of the Namoi at the Narrabri bore, and these deposits probably commenced to form in the Cretaceous. Again, eroded masses of them are met with at the level of the Cretaceous peneplain (Mole Cycle), but the lavas and tuffs of these rocks have been denuded away and only the hypabyssal forms left.

All the other rocks described from this region, both hypabyssal and volcanic, with the exception of the Carboniferous rhyolites and rhyolitic tuffs of Maule's Creek, and perhaps the Boggabri rhyolites, may be looked upon as differentiation-products of the same magma. The Boggabri rhyolites, tuffs and pitchstones are doubtful both as to age and relationship.

The latest basalts in the Nandewars are calcic, but often free of olivine, and are best looked upon as the basic residuum of an alkaline magma.

The augite-porphyrites and bronzite-porphyrites of Cretaceous age are often rich in analcite, and may therefore also be related to the alkaline series, but this is extremely doubtful.

Minerals of The Nandewar Rocks.

i. The Ali-trachytes, Ali-rhyolites, Bostonites, and related porphyries contain many minerals in common.

(a) Abundant or common.—*Felspar* occurs in phenocrysts and also finely granulitic in the base. The phenocrysts are usually bounded by the faces *m* (110), *a* (100), *n* (021), and *b* (010). Sometimes they are tabular parallel to *b* (010), which is the typical sanidine habit, and have the usual crosscracks developed. Sometimes they are prismatic, thickened also in the *c* direction; *à* (crystallographic) is the usual direction of elongation. Carlsbad twinning is generally observed, but in some rocks the Baveno type is even more frequent. Manebach twinning sometimes occurs. There are, therefore, Baveno twins forming nearly square prisms elongated in the direction of crystallographic *a*, Baveno twins tabular parallel to *b*, prismatic Carlsbad twins, and Carlsbad twins tabular parallel to *b*. In some Carlsbad twins the faces *x* and *c* are well developed (N.30). Inclusions of albite and of groundmass are occasionally seen in the phenocrysts of some rocks (*e.g.*, N.30); in others it is not unusual to find inclusions of quartz in them, in others again, microperthitic intergrowths of potash and soda felspar or cryptographic intergrowths of quartz and felspar.

In the Dingo Creek *Bostonite*, N.51, the extinction angle is from 8° to 11° on crystallographic *à* (edge *b c*), indicating a variety of sanidine rich in soda. The form of the crystals is tabular or elongated in the *à* direction. The extinction is shadowy, indicating ultramicroscopic twinning. Inclusions of quartz and apatite occur within the phenocrysts. By picking a section cut nearly parallel to the plane of the optic axis it was ascertained by use of the selenite plate that $\mathfrak{a}$ is near a normal to the *à* axis. The square sections (*i.e.*, sections at right angles to *a*, the direction of elongation) showed an axial cross in the same slide. Therefore

$$Bx^{a} = \grave{a}, \textit{ i.e}, \text{ nearly at right angles to } \mathfrak{a}.$$

These crystals are therefore negative. They must be looked upon as a variety of sanidine very rich in soda.

Associated with such phenocrysts in the same and other rocks occur Carlsbad twins of similar habit, in which it was determined with the selenite plate that

$$Bx_a = \mathfrak{a}.$$

These crystals are therefore positive and must be looked upon as a variety of anorthoclase closely related to albite.

Hence we have in general two types of felspar phenocrysts.

Optically positive, usually prismatic, crystals of the sanidine habits with a refractive index less than canada balsam, Carlsbad or Baveno twinning, cleavage parallel to *c* and almost at right angles to *b*, and extinction angle from 0°-12° on edge *b c*. This felspar is a variety of anorthoclase in which the albite molecule predominates.

Optically negative crystals either prismatic with square sections or tabular parallel to *a*, showing Carlsbad or Baveno twinning. Their extinction angles vary from 0°-10° on the edge *b c*. They are clear and furnished with crosscracks like sanidine. This felspar is assignable to the species of orthoclase (sanidine) and anorthoclase sanidine. Albite inclusions are common.

These two forms may occur together in the same rock or intergrown in the same crystal, and numerous intermediate types exist.

The felspars of the base are referable in different rocks to different species varying from pure sanidine to albite. Usually the predominating felspar of the phenocrysts is abundant or predominating also in the base.

Hornblende occurs sometimes in rods, sometimes in minute grains clumped together in dendritic aggregates forming a poikilitic intergrowth with felspar. It is frequently replaced by hæmatite and occasionally in weathered rocks by limonite. It has the usual appearance of the arfvedsonite already described in the paper dealing with the Warrumbungle Mountains.

In N.46, a rock rich in blue amphibole and very poor in ægirine, it was ascertained that in the blue amphibole $Bx_a = \mathfrak{c}$, hence the mineral is positive. The extinction was nearly straight and the absorption scheme proved to be

$\mathfrak{c}$ (deep blue-black) $>$ $\mathfrak{b}$ (lavender) $>$ $\mathfrak{a}$ (bright light green).

N.59 B is a rock in which nuclei of dark arfvedsonite or riebeckite of a deep blue-black colour are surrounded by a lighter-coloured arfvedsonite or ægirine, sometimes the one, sometimes the other. The dark arfvedsonite is like that of N 46; ægirine is the dominant ferric mineral. The light-coloured variety of arfvedsonite, however, displays peculiar properties. $Bx_a = \mathfrak{a}$, hence it is negative, and the absorption is

$\mathfrak{c}$ (bright greenish-blue .> $\mathfrak{b}$ (lavender) .> $\mathfrak{a}$ (greenish-yellow). Possibly this mineral may be an aberrant variety of ægirite.

Pyroxene varies from pure ægirine to ægirine-augite. It answers to descriptions given of the same mineral in the Warrumbungle Petrology.

(b) Minerals sparingly represented.—Many of these are represented only by grains of such minute size that it has not been found possible to make an exhaustive examination of optical properties.

Cossyrite (?) occurs very sparingly and is recognised in sections where it occurs in extremely fine-grained poikilitic aggregates, by its deep brown colour, strong pleochroism and cleavage angle of 65°.

Katophorite (?) occurs in dendritic aggregates of somewhat acicular crystals often surrounded by hæmatite or a zone of arfvedsonite and ægirite. This mineral is strongly pleochroic in colours of deep purple, red, fine deep red, brown, yellow, and greenish-yellow. There are apparently several varieties graduating into arfvedsonite, cossyrite and ferrite. This mineral commonly forms only the kernel of crystals of ægirite and arfvedsonite. It appears to me for this reason that the arfvedsonite and ægirite are products of pneumatolysis commencing after the brown hornblendes had commenced to form. This vapour-action often completely decomposed the original katophorite, leaving ferric oxite (ferrite) in its place, and the Na_2O, SiO_2, TiO_2, etc., of the molecule were redistributed amongst other minerals of the rock. Only in this way can I explain that we often meet with sheets of trachyte with the hornblende completely metamorphosed to ferrite or hæmatite while it has not been subjected to any more weathering than adjoining arfvedsonite trachytes.

Wöhlerite (?), a yellow mineral in acicular crystals, nonpleochroic or but slightly so; double refraction strong; refractive index medium. This mineral shows the characteristic yellow cracks of wöhlerite and is apparently the product of the pneumatolytic action which broke down the katophorite molecule. It is more abundant in ægirine-ferrite trachytes than in the rocks rich in arfvedsonite.

Lavenite (?) or Rosenbuschite (?) appears to be present in some of the rocks, but has not been identified with certainty.

Tridymite occurs occasionally in vesicles; often yellowish, almost isotropic opal is seen; occasionally banded chalcedony replaces it.

Meionite (?) (or an allied scapolite mineral such as wernerite or marialite) in clear glassy or milky-white crystals, showing a good cleavage, weak double refraction and medium refractive index, is sometimes present.

Where quartz is very rare or wholly absent, sodalite (or nosean), nepheline and katapleiite have occasionally been observed to occur.

In the phonolitic rocks of the Nandewar region we find, in addition to those occurring in the trachytes, nepheline, a mineral of the sodalite group, cancrinite, katapleiite (?), geisikite (?), liebnerite (?), zeolites and calcite. Analcite often occurs.

ii. The Ali-syenites, porphyries and porphyrites contain many of the above-mentioned minerals, but in the more basic varieties soda-lime felspars predominate as phenocrysts, and albite or potash-soda felspar (anorthoclase, soda-sanidine) in the groundmass. In different rocks different soda-lime felspars are met with varying from albite to medium labradorite.

In some reddish-coloured varieties of syenite-porphyry occurring in sills about Bullawa Creek the felspar phenocrysts have a refractive index less than canada balsam. In outline they are in some rock-varieties like orthoclase, in others they give rhombic sections (rhomben-porphyr). Twinning is on the Carlsbad plan, and the two cleavages are nearly at right angles to one another. In addition a fine striation due to polysynthetic twinning is readily observed. This felspar is a microcline microperthite (or anorthoclase microperthite). Often cloudy microcline (moirirten-microclin) and gitter microcline are abundant constituents. The base consists in these rocks essentially of anorthoclase. These soda-potash felspars, so common in the Christiania region, are extremely abundant and well developed in the Nandewar alkaline rocks.

Arfvedsonite is rare in these rocks, but occurs sometimes.

Ægirine is occasionally present, but more often it is represented by an ægirine-augite or light green diopside (salite). Olivine is never present, and in fact the analyses display so low a magnesia percentage that all this constituent must be incorporated in the ægirine-augite (see Analyses, Table i. and Calculations of the norm, Table ii.). The main bulk of these rocks consists invariably of felspar, the other constituents never attaining great abundance.

As minor constituents we find nepheline (in the groundmass), decomposition-products after nepheline such as cancrinite, katapleiite, geisikite (?), liebnerite (?) and zeolites; also apatite, fluorspar, zircon, ferrite, magnetite, hæmatite, ilmenite. Chlorite, secondary after ægirine-augite, is a common constituent in many of the darker porphyrites. Occasionally sodalite is present. Quartz may also occur.

iii. The post-trachytic basic lavas have many similarities with the phonolitic and other intermediate lavas, in texture, mineral composition, and chemical composition. They are poor in magnesian minerals, olivine being usually absent (*cp.* the basalt of the Sandilands Ranges, New England).

iv. The basic rocks of greater antiquity than the trachytes, namely the dolerites intruding the Permo-Carboniferous strata at Bullawa Creek and Bobbiwaa Creek, form a distinct group. The pyroxene is a deep brown highly pleochroic titaniferous augite accompanied by a diallage. Olivine is abundant, and the felspar is very calcic. Some of these rocks, however, contain *analcite* in fair abundance, a fact which may be an indication that even then there was a tendency for this to be a sodic province.

N.62. Loc.: hill at junction of Manilla and Narrabri roads, 3½ miles north of Boggabri. Age uncertain. (Plate l., fig.1).

Handspecimen a dark green to black rock, showing fluxion structure and perlitic cracks. A few vesicles and idiomorphic phenocrysts of orthoclase, oligoclase and albite occur in it. This rock occurs in the form of a narrow dyke at the foot of the hill mentioned, which consists essentially of rhyolite and rhyolitic tuff.

Microscopic appearance: texture hypohyaline, porphyritic, with perlitic structure in the glassy base.

Constituents : the base which forms the bulk of the rock consists of a greenish glass showing beautiful perlitic cracks and groups of globulites. Scattered about in some abundance we find beautiful idiomorphic phenocrysts of felspar, some of which increase in basicity from the interior outwards. Often the core is orthoclase, an intermediate zone anorthoclase, and the outer zone albite or oligoclase. Neither in mineral composition nor in chemical composition does this rock show decided resemblance to the alkaline rocks of the Nandewars, yet it is not very distantly removed from them.

Name: Perlitic Pitchstone. Magmatic name, Riesenose (see Tables i. and ii.).

Note.—This rock is associated with holocrystalline, hemicrystalline and cryptocrystalline rhyolites.

N.67. Loc.: The Pinnacles; Maule's Creek. Age: Carboniferous.

Handspecimen a reddish conglomerate-like rock with both the rounded pebbles and the finer matrix consisting of rhyolitic material.

In section the pebbles were seen to consist of a normal rhyolite (qnartz, orthoclase and a little chlorite) and to have been rounded by the action of water. The matrix consists of fragmentary grains of quartz and felspar and volcanic ash consisting of the same minerals and a great abundance of glass fragments in the form of minute tubes, and boomerang-shaped and bone-shaped, branched and jagged rods. All this material is of pure volcanic origin, but has evidently been redistributed by the action of water. Subsequent alteration due to regional metamorphism has led to the commencement of secondary crystallisation or regeneration of crystals. Much of the material, originally glassy, is therefore partially devitrified.

Rocks of this kind, which must be termed *Tuffy Rhyolite Conglomerates*, prove without doubt that submarine eruptions and land eruptions were in progress near an old shoreline and the materials ejected were redistributed by the waves.

Interbedded with them are found rhyolites, devitrified porphyritic pitchstones and quartz porphyries.

N.17. Loc.: laccolite on Dingo Creek, branch of Bullawa Creek. (Plate 1., fig.2).

Handspecimen a coarse-grained dolerite in some varieties of which large augite phenocrysts occur, but the type here described is rather even-grained. Near the edges of the laccolite this rock graduates into a black aphanitic basalt with occasional amygdules. The intrusion is older than the alkaline rocks.

Texture holocrystalline, seen under the microscope to be uneven-grained and porphyritic, having crystals of most varying sizes. Fabric hypidiomorphic granular, and ophitic.

Constituents : basic felspar and titaniferous augite are the two most abundant constituents, occurring in about equal proportions and forming about 60-70 % of the mass. The next constituent in order of abundance is olivine, forming between 10 % and 20 %. Then follow magnetite and ilmenite, forming upwards of 5 %. Decomposition-products such as serpentine, chlorite and leucoxene also occur in notable amount. As an accessory minor constituent apatite (in long thin needles penetrating the other minerals) deserves mention.

Note.—In some varieties of this rock-type analcite forms a constituent mineral.

Order of consolidation: felspar needles frequently penetrate some distance into augite crystals but never to the core.

{ Magnetite
{ Ilmenite
Olivine
Apatite
Augite
Felspar
(Analcite when present)

Name: Ophitic Olivine Dolerite or Diabase. Magmatic name, Kentallenose (see Tables i. and ii.).

Closely allied to N.17 is a rock from the Alpha (Diamond Mine, Bullawa Creek, 13 miles N.E. of Narrabri, N.S.W., of which the following description has been supplied to me by my old friend, Mr. G. Saunders, B.E.

Handspecimen resembles a basalt, being of a dark colour and moderately fine-grained. It occurs as a dyke about 8 feet wide. Bands of calcite occur in it, and due to these bands the rock crumbles away on exposure. It intrudes sandstone, and capping these rocks there is an alluvial deposit in which diamonds, sapphires, zircon and gold have been noticed.

Microscopic Description.—Texture holocrystalline; grainsize medium with a few large phenocrysts of augite and plagioclase; fabric camptonitic and ophitic.

Constituents in order of decreasing abundance are (1) felspar, (2) titaniferous augite, (3) colourless diopside in phenocrysts, (4) olivine, (5) serpentine, (6) magnetite, (7) grains of red olivine (fayalite), and (8) apatite.

I have examined a slide of it sent to me by Mr. Saunders, and I find it to be a rock closely related to N.17. The felspar is a basic labradorite, and it as well as the olivine and augite occur in two generations.

Mr. Saunders also kindly forwarded me a slide of another rock of the same kind obtained from a depth of 2,015 feet in the bore-hole at Narrabri. This rock is holocrystalline, hypidiomorphic granular, medium-grained, and porphyritic in augite, magnetite and felspar. The felspar consists of lath-shaped labradorite crystals; the augite is highly titaniferous and occurs in fine reddish-brown idiomorphic crystals which frequently enclose felspar in an ophitic manner. Titaniferous magnetite occurs in corroded phenocrysts; ilmenite is also present. Apatite is common as inclusions in both the augite and the felspar. Large patches of the base consist of a clear colourless isotropic mineral with a low refractive index. This mineral was the last to consolidate, and is probably analcite. The rest of the ground-mass consists of the second generation of the minerals already mentioned.

Name: Ophitic Analcite-Olivine-Dolerite or Diabase.

N.19. Loc.: edges of laccolite, Dingo Creek.

Handspecimen dark basaltic-looking rock with white amygdules.

Texture holocrystalline, uneven-grained but fine-grained with pilotaxitic fabric.

Composition: this rock consists of basic labradorite felspar in laths decomposing to analcite, zeolites and other products, automorphic but somewhat corroded grains of titaniferous augite, very corroded and rounded olivine grains, idiomorphic magnetite granules, analcite and decomposition-products. The white amygdules consist of analcite and zeolites.

Name: Pilotaxitic Olivine Basalt (or Diabase).

N.56 consists of a fine-grained basalt exactly like N.19, and occurs on the borders of the basic laccolite at the head of Bobbiwaa Creek.

N.57, collected from the core of the same Bobbiwaa laccolite, is a coarse-grained dolerite (or diabase) exactly like N. 17, described above.

Linking the foregoing basic rocks to the alkaline series are certain remarkable essexites, of which I have found rolled specimens in the creeks, but which I have not met with *in situ.*

N.28 is a reddish coarse-grained rock, in handspecimen not unlike N.27 (described hereafter). Loc.: Thor's Creek, Bullawa Creek.

Microscopic examination: Texture holocrystalline, hypidiomorphic granular, uneven-grained rock, showing ophitic structure.

Constituents (in order of decreasing abundance): (1) Titaniferous augite studded with interpenetrating felspar needles and apatite inclusions; it occurs in phenocrysts which are more or less corroded and fractured. (2) Bronzite with well-defined crystalline outlines. (3) Ilmenite. (4) Analcite (interstitial). (5) Chlorite replacing biotite. (6) Bytownite and anorthite felspar in laths. (7) A little biotite. (8) Apatite needles. (9) Zircon. (10) Zeolites of the mesolite group. (11) Interstitial orthoclase. (12) Serpentine in irregular patches.

Name: Ophitic Analcite Essexite allied to Teschenite.

Note.—This rock seems to have been formed by a kind of magmatic mixture of an alkaline rock with a dolerite like N.17. The mixture may have taken place either by an alkaline magma having intruded, partially fused and assimilated a dolerite, or wholly by pneumatolytic processes. The broken nature of the pyroxene phenocrysts and the irregular serpentine patches representing the remnants of resorbed olivines support the first supposition. The second alternative receives support from the facts that biotite has developed and analcite is abundant. When we consider the basicity of the felspar laths and their fresh appearance it becomes evident at the same time that the analcite could not have been primary, nor can it have been formed by decomposition of the felspar. Therefore it is concluded that the magmatic vapours from the alkaline intrusions caused a partial recrystallisation in this basic rock, introducing K_2O to form the interstitial orthoclase and biotite,

SiO_2 to change olivine to bronzite, and water to break up the original felspar molecules into anorthite and analcite. Zircon (ZrO_2) was introduced at the same time.

Taking all into consideration it appears that there was *magmatic mixing*, accompanied by *pneumatolytic action.*

N.18. Loc.: Sill iii. at Dingo Creek (Pl. lii., fig. 1).

Macroscopic characters: the handspecimen (Pl. lii., fig. 1*a-b*) presents a remarkable appearance. It is studded with gigantic phenocrysts and fragments of crystals of a black mineral with a dull lustre not unlike that of gadolinite. In general outline this mineral reminds one of cassiterite, but its good cleavage in three directions and its brittleness show that we have a pyroxenic mineral to deal with. In addition, the rock contains an abundance of fragments of crystalline aggregates, many of which have such regular and straight outlines as to be suggestive of pseudomorphs after olivine. One of the minerals composing the fragments is seen to be a green olivine. Many of the fragments are $1\frac{1}{2}$ inches or more in length and over $\frac{1}{2}$-inch in width. The black phenocrysts attain a length of 3 to 4 inches, and a diameter af $2\frac{1}{2}$ to 3 inches. In addition we may notice phenocrysts (up to 1 inch in diameter) of a brown spinel, and a black microcrystalline groundmass.

The rock weathers to a reddish clay, and decomposing specimens have always a reddish crust of iron oxides. Occasionally large crystals of biotite (or paragonite) attaining a diameter of 1 to $1\frac{1}{2}$ inches, and a thickness perpendicular to the cleavage of about $\frac{1}{2}$-inch, are met with. Calcite or dolomite occurs abundantly, forming amygdules.

This rock forms a sill, having a thickness of about 3 feet, and dipping S.E. at 25° (S_1 fig.), capped by and overlying cherty, metamorphosed, Permo-Carboniferous shales containing *Glossopteris*, *Gangamopteris* and *Noeggerathiopsis.* Intruding the same shales about 30 feet higher up the series we have a sill of felspar porphyry with a trachytic matrix (bostonite). The succession of strata observed from the bottom of the cliff to the top is seen in the following statement :—

Dip S.E. at 25°	Top of hill—	Trachyte under which we have conglomerate, thickness not estimated.	
	Top of cliff—	The same conglomerate.	
	Then—	Sandstone, 30 feet.	
		Cherty Mudstones, 20 feet.	
		Felspar Porphyry Sill (Bostonite), 6 feet.	
		Cherty Mudstone, 9 feet	With Permo-Carboniferous fossils.
		Soft Blue Shales, 6 feet	
		Cherty Shales, 4 feet	
		,, ,, 7 feet	
		Black Shale, 6 inches	
	Bottom of Cliff, Dingo Creek.	Sill with black phenocrysts and fragments, 2ft. 9in., then Sandstone, 3 feet.	
		White Shales, 1 foot.	
		Cherty Mudstones, thickness unknown.	
		Level of Creek.	

Microscopic examination : texture holocrystalline, extremely uneven-grained on account of the monstrous phenocrysts set in the microcrystalline base. The base is quite aphanitic, but with a $\frac{1}{4}$-inch objective it is resolved and appears to be holocrystalline with a camptonitic fabric.

Composition : the crystal aggregates or fragments are seen under the microscope to have a more broken outline than the handspecimen shows. They consist of olivine, light greenish diopside, enstatite and colourless augite in hypidiomorphic to allotriomorphic crystals, the whole aggregate having a hypidiomorphic granular texture. Between the crystals are strands of a white fibrous chloritic decomposition-product, apparently margarite. Fragments of picotite are also present. The black phenocrysts are somewhat corroded along the margin, having a resorption rim resembling the celyphitic border of garnet. They consist of a species of hypersthene or amblystegite. The mineral has three well marked cleavages, two of which are at right angles; there are also two pinacoidal partings to which extinction is parallel. The pleochroism is weak, and the double refraction is also weak, being about the same as that of labradorite.

The mineral was determined to be biaxial and optically negative with a dispersion less for red than for blue ($\rho < v$). The brown spinel which occurs in crystals and fragments of all sizes in both the inclusions and the base appears to be picotite. The brown mica which occasionally forms huge phenocrysts occurs also in minute grains in the base. The fine-grained base consists of allotriomorphic olivine and augite grains, picotite grains, a little biotite, all evidently xenogenic, and of autogenic minerals including laths and needles of brownish titaniferous augite, needles of colourless diopside, rutile in needles, zircon in grains, and felspar. Both albite and orthoclase occur, and in addition there is nepheline and analcite. These last four minerals mentioned were the last product of consolidation. Yet they have a strong tendency to idiomorphism, except the analcite which is mainly secondary.

To sum up: the specimen N.18 is a lamprophyric rock; it contains xenoliths of enstatite-peridotite, and xenocrysts of a species of rhombic pyroxene, of biotite (lepidomelane ?), of picotite, and of olivine and augite. The base has an almost panidiomorphic structure, the so-called camptonitic fabric, and contains, in addition to the xenocrysts, titaniferous augite, diopside, rutile, zircon, albite, orthoclase, nepheline and analcite, and possibly a little glass. The decomposition-products are margarite, bastite (schiller spar), serpentine and hæmatite. Calcite is particularly abundant, especially in the form of amygdules.

Name: Monchiquitic Lamprophyre. Magmatic name, Rossweinose (see Tables i. and ii.).

N.54. Loc.: hill on the Spring Creek Road, 2 miles N.W. of Narrabri.

Handspecimen has the appearance of typical porphyritic basalt. The age of the mass, which is associated with basic tuffs and breccias, is probably later than the alkaline series. This rock probably belongs to the late Tertiary—Pliocene—series of basaltic eruptions.

Texture almost holocrystalline, very uneven-grained, with hyalopilitic fabric.

Composition: the phenocrysts consist of basic andesine, olivine and greenish diopside. The felspars are sometimes zoned and show albite, pericline and Carlsbad twinning, and contain numerous inclusions of magnetite in glassy matrix. The olivines are slightly corroded, and the diopside is greatly corroded and resorbed.

The groundmass is even-grained and very fine-grained, and consists of felspar-laths (labradorite), augite of the second generation in idiomorphic grains, olivine grains, glass and hæmatite. The lastmentioned is an original constituent.

Name: Hyalopylitic Porphyritic Olivine Basalt.

The foregoing descriptions are of rocks which have no very marked relationship with the lavas of the alkaline series. All the other rocks about to be described from this area are closely interrelated and definitely fall into the alkaline division.

N.27. Loc.: Thor's Creek, branch of Bullawa Creek.

Handspecimen of a reddish colour not unlike N.28 already described, but the microscope reveals important differences.

Macroscopically it appears coarse-grained, but in reality it has a fine-grained base.

Texture holocrystalline, uneven-grained, porphyritic, with hypidiomorphic granular fabric.

Constituents: the phenocrysts consist chiefly of cloudy microcline and anorthoclase microperthite containing an abundance of inclusions of apatite and zircon. The microperthite felspar is commonly enveloped by a zone of pure orthoclase with straight extinction. Smaller phenocrysts of magnetite and hæmatite are also present.

The granulitic groundmass consists of orthoclase, nepheline, apatite, magnetite, hæmatite and other iron ores, yellowish-green pleochroic acmite, and rutile.

The apatite occurs in greenish-grey and bluish-grey idiomorphic hexagonal prisms capped with a pyramid at either end and longitudinally striated.

Rutile is abundantly represented in long microscopic needles. The nepheline is interstitial. A little wöhlerite (?) is also present. The magnetite appears to be partly secondary after arfvedsonite.

Name: Nepheline-Acmite-Syenite Porphyry, allied to Sölvsbergite.

A rock closely allied to the preceding is N.8 (Pl.1., fig.3), which also occurs as a rolled specimen in Bullawa Creek. It is holocrystalline, porphyritic, with a fine-grained base, and has a trachytic fabric inclining to camptonitic.

The felspar phenocrysts have lozenge-shaped outlines in the sections like the felspar of rhomben-porphyr. They are twinned on the Carlsbad plan and exhibit a very fine polysynthetic twinning as well which shows that they belong to the species anorthoclase. The refractive index is less than that of canada balsam. Reddish iron ores (hæmatite) occur in dendritic aggregates secondary after a hornblende of the riebeckite group. The base consists essentially of lath-shaped microlites of sanidine, between which are studded minute stunted rods of ægirine, a little primary as well as secondary magnetite, and some interstitial quartz.

This rock is a somewhat decomposed sölvsbergite. It differs from N.27 mainly in that it is more decomposed and contains a little quartz instead of nepheline.

Still more closely allied to N.27 is another rolled specimen, N.9, from Thor's Creek. Its texture is the same. The phenocrysts consist chiefly of orthoclase, occasionally of microperthite. The orthoclase of the base is allotriomorphic in more or less rounded grains. There are numerous hæmatite or ferrite skeletons replacing what was originally a hornblende. Both idiomorphic primary, and dusty secondary, magnetite occur. Apatite is abundant and ægirine occurs sparingly in the base. The ægirine is of a bright malachite-green colour, strongly pleochroic, but of a colour so deep as to almost obscure birefringence.

This rock must be referred to the species Sölvsbergite.

N.11. Loc.: branch (E.) of Oakey Creek under Mount Odin. (Pl.1., fig.4).

Handspecimen : a dark greenish rock which on close inspection is readily seen to be porphyritic, although the phenocrysts are so dark in colour that they might easily escape notice at first glance. This rock occurs as a sill about 20 feet thick with Permo-Carboniferous Glossopteris shales and sandstones above and below.

Texture holocrystalline, porphyritic, with hypidiomorphic granular texture approaching the panallotriomorphic.

Constituents : the phenocrysts consist of felspar and diopside. The felspar phenocrysts are lozenge-shaped and consist of anorthoclase or microcline-microperthite enveloped by a zone of orthoclase. The inner portions have an extinction angle of about 10°, the outer zone having straight extinction. The refractive index of all parts is less than that of canada balsam. The diopside occurs in idiomorphic phenocrysts. In addition there are pseudomorphs after phenocrysts of hornblende. These usually consist of a brown ferrite skeleton enclosing a heterogeneous mass of secondary minerals, including chlorite, hæmatite, magnetite, sericite, some isotropic analcite or sodalite (?), and zeolites. They probably represent what was originally a brown soda-amphibole. Some of these pseudomorph phenocrysts contain small remnants of a reddish-brown very highly pleochroic mineral (apparently barkevicite).

The groundmass consists of orthoclase felspar, green ægirine-augite granules, nepheline and secondary minerals including chlorite and micaceous alteration-products after nepheline, such as geisikite, liebnerite, etc.

Apatite occurs sparingly as idiomorphic phenocrysts and also in smaller needles in the groundmass.

Name : Augite-Nepheline-Syenite-Porphyry or Pulaskite Porphyry. Magmatic name, Phlegrose (see Tables i. and ii.).

N.13. Loc.: This rock occurs as a fine-grained included mass of irregular shape and a couple of feet in thickness in the sill rock just described (N.11).

Handspecimen dark green, aphanitic.

Texture holocrystalline, microcrystalline, panidiomorphic granular.

Constituents: (1) lath-shaped crystals of labradorite (2) Ægirine in short prisms showing strong pleochroism in greens and blues, and straight extinction. (3) Idiomorphic prisms of nepheline and a minute quantity of the same mineral occurring interstitially. (4) Magnetite. (5) Decomposition-products including chlorite, pinite pseudomorphs and kaolin.

Name: Camptonitic Tinguaite.

This rock represents a fragment of the earliest consolidated portion of the magma torn from the walls of the reservoir by the rising lava.

Closely allied to this rock is a fine-grained nepheline phonolite found in a branch (B) of Oakey Creek (N.10). The acicular felspars are somewhat decomposed and consist of orthoclase and albite. Nepheline occurs in the groundmass. The femic constituent is a green nonpleochroic augite with very oblique extinction (about 46°, probably salite); it is surrounded by dark borders. Dusty magnetite, secondary after an amphibole, occurs, as well as other decomposition-products like kaolin. The computation of the analysis gives free quartz in the norm; this is probably due to decomposition and secondary silicification.

N.12. Loc.: Branch (E) of Oakey Creek. (Plate li., fig.1).

Handspecimen: this rock has a dark green base in which are studded gigantic idiomorphic prismatic felspar phenocrysts often attaining a length of more than an inch, and a diameter of over half-an-inch; and usually regularly octagonal in cross section. The rock forms sills at the head of the branches of Oakey Creek under Mount Odin.

Texture holocrystalline, coarsely porphyritic with a hypidiomorphic granular base.

Constituents: the huge felspar phenocrysts consist of acid labradorite and andesine, the extinction angle in symmetrical sections varying from 10° to 25°, but in most cases it is about 20°. The refractive index is greater than that of canada balsam. Twinning is on the Albite law, but pericline twinning is also met with. There are no other phenocrysts. The groundmass consists of a sanidine-like felspar which may be either orthoclase or anorthoclase. This occurs as microlites. Idiomorphic ægirine augite grains decomposing to chloritoid, apatite needles, greenish micaceous fibrous decomposition-products of the pinite group, finely divided magnetite, hæmatite, a little nepheline and cancrinite are also present.

Name: Labradorite Porphyry. Magmatic name, Andose (see Tables i. and ii.).

N.26. Loc.: Branch (C) of Oakey Creek.

Handspecimen a green, somewhat decomposed coarse-grained rock.

Texture holocrystalline, even-grained, hypidiomorphic-granular.

Composition: the main constituent is felspar in hypidiomorphic crystals which have been largely saussuritised, chloritised and kaolinised; it contains as inclusions magnetite, stout needles of apatite, and small idiomorphic grains of fluorite. The alteration of the rock has led to the production of a certain amount of secondary felspar in needles within the original phenocrysts. The original felspar was probably an albite surrounded by a zone of microperthite, decomposition having effected the exterior more than the interior. Representing what was originally augite and conforming to its crystalline outline, we have aggregates of chlorite and green chloritoid, sometimes serpentine as well. These occasionally contain a nucleus of uralite. Remarkable skeletons of ilmenite and magnetite are present in abundance. A little nepheline occurs, and decomposition-products after nepheline are fairly common. These include katapleiite, cancrinite, liebnerite pseudomorphs, etc. Rutile needles are very abundant. The other decomposition-products present are kaolin, chlorite, chloritoid, serpentine, hæmatite, saussurite, etc.

Name: Altered Augite-Nepheline-Syenite near Laurdalite.

N.14. Loc.: Branch (A) of Oakey Creek.

This rock occurs as a sill. In microscopic structure and mineral composition it closely resembles N.8 and N.9, and is therefore a sölvsbergite, or nordmarkite-porphyry.

Remarks.—The alkaline rocks dealt with so far are all derived from the sills underlying Mount Odin. Underlying the whole of this mountain there is probably a large laccolitic mass, from different levels of which the sills are offshoots. All these rocks are undoubtedly differentiation-products of the one mass, presenting numerous features in common, chief of which are (1) the occurrence of nepheline and pseudomorphs after nepheline, (2) the occurrence sparingly of apatite phenocrysts of a greenish colour capped with pyramids at both ends and exhibiting a fine longitudinal striation, (3) the occurrence of soda-bearing pyroxene in the base.

The chemical analyses correspond excellently to the petrological compositions. Thus N.11, though the darker in colour, is much more acid than N.12, and contains much less of the iron oxides and lime. The dark colour of N.11 is due to the phenocrysts consisting of dark cloudy *microperthite* felspar, while the more basic phenocrysts of N.12 consist of white labradorite.

The alteration-products in these rocks are hard to determine. I have spent much time in trying to work out the exact nature of the fine micaceous pseudomorphs without avail. There is, however, no doubt that they sometimes approximate very closely to liebnerite and sometimes to geisikite, though usually analcite, calcite and zeolites occur with them. These minerals are secondary after nepheline and are associated with others such as cancrinite and katapleiite of similar origin. Sometimes the aggregates show definitely the outlines of the original nepheline crystals.

I have slides of nepheline tinguaite from the range between Spencer's Creek and the Snowy River (Guthrie Range), Mt. Kosciusko, which show exactly the same decomposition-products.

Associated with these minerals in the Nandewar nepheline rocks are certain chloritic, sericitic, and pinite alteration-products after ægirine-augite, felspar and soda-hornblende. This class of alteration-products resembles the other so closely that it has not been found possible to distinguish between them except where they form definitely pseudomorphs of regular outline.

All the alkaline rocks so far described contain an abundance of minerals which gelatinise with dilute HCl and stain with malachite-green.

The order of consolidation in these rocks usually was as follows : —

1. Magnetite : ilmenite ——————————
2. Plagioclase ——————
3. Apatite ————————
4. Hornblende —————
5. Orthoclase ——————————
6. Augite (Ægirine) —————
7. Nepheline ——————

N.25. Loc.: base of Ningadhun Rock.

Handspecimen white in colour with a few dark specks; light in weight, probably due to an abundance of minute vesicles; soft and friable like sandstone.

Texture holocrystalline ; very fine-grained, microcrystalline ; with trachytic fabric.

Composition : the main constituent is felspar, which forms about 90% of the rock; it occurs of both prismatic and tabular habits, the phenocrysts being chiefly sanidine of tabular habit, the remainder being partly sanidine and partly anorthoclase, the latter showing under the high power a delicate striation due to multiple twinning on various laws. Carlsbad and Baveno twinning are both common. Phenocrysts having an hourglass appearance between crossed nicols are probably Baveno fourlings. Next in order of abundance comes ægirine, which occurs both as corroded phenocrysts surrounded by decomposition and corrosion rims and as finer acicular crystals in the base. A deep blue hornblende (arfvedsonite or riebeckite) is represented fairly plentifully as minute highly pleochroic rods. Yellow and reddish iron ores and chlorite occur as decomposition-products. No nepheline or quartz is recognisable, but the rock stains slightly with malachite-green after gelatinisation with dilute acid.

Name : Trachytic Ægirine Trachyte. Magmatic name, Phlegrose.

Note on N.30 : the specimen analysed from Ningadhun is a similar rock. It differs from N.25 only in that ægirine is relatively more abundant, riebeckite rather less so, occurring only as occasional grains, and in the presence of a little interstitial quartz (*cp.* Tables i. and ii.).

N.31. Loc.: base of Ningadhun Rock.

Handspecimen: a dark porphyritic rock showing felspar phenocrysts in an aphanitic base. It was taken within a few feet of N.30 and N.25, but belongs to a totally different flow.

Texture apparently holocrystalline, the isotropic patches being referable to analcite and other decomposition-products; porphyritic, and with cryptocrystalline to microcrystalline pilotaxitic base which may be partly devitrified glass.

Composition: the phenocrysts are corroded and partially resorbed at the edges, and consist of andesine. A brownish-green hornblende has been present in the form of phenocrysts, but is now almost wholly replaced by chlorite, secondary magnetite and hæmatite. The groundmass consists of microlites of andesine, isotropic or almost isotropic decomposition-products and nepheline, a few stunted rods of a colourless pyroxene, acicular crystals of a yellow pyroxene which may be a relative of wöhlerite, magnetite and minute cubes of green spinel (pleonaste). A number of decomposition-products are present, amongst which the chief seem to be hæmatite, chlorite and dusty magnetite after hornblende and pyroxene; and sericite after felspar; also natrolite and opal infilling vesicles.

Name: Phonolitic Andesite.

N.49. Loc.: slopes of Mount Ningadhun. (Plate li., fig.3).

Handspecimen reddish-brown in colour, very hard, and aphanitic.

Texture apparently holocrystalline, microcrystalline to cryptocrystalline base, with phenocrysts; trachytic fabric.

Composition: the main constituents are microlites of orthoclase and albite, nepheline in corroded phenocrysts whose resorbed edges show alteration to cancrinite and geisikite, a highly pleochroic brown hornblende, probably cossyrite, with hæmatite and magnetite and sphene as decomposition-products, needles of a brown pyroxene not unlike wöhlerite, and glass. The rock is amygdaloidal, the infillings of the vesicles consisting of zeolites and opal.

Name: this rock is apparently a Cossyrite-Nepheline Trachy-Andesite, the high TiO_2 percentage shown in the analysis being confirmatory of the presence of cossyrite and wöhlerite. Magmatic name, Monzonose (*cp.* Tables i. and ii.).

Note: it is significant, in connection with the occurrence of quartz in the calculated norm, that the nepheline occurs as corroded phenocrysts, the base being andesitic. Further, the occurrence of opal shows that secondary silicification has taken place.

Both N.31 and N.49 are closely related chemically and mineralogically to the remarkable corundum basalt found at Billy King's Creek, south of Coonabarabran, in the Warrumbungles. They are all the basic differentiation-product of a magma exceedingly rich in Al_2O_3, Na_2O, and TiO_2, and very poor in MgO and FeO, just as the arfvedsonite trachytes (as N.25 and N.30) form the more acid differentiation-product.

The richness of the magma in TiO_2 is especially striking for the Nandewar Mountains. In many of the rocks where conditions have not been favourable for the formation of titaniferous amphiboles and pyroxenes, the titanic acid has crystallised out in the form of an abundance of sagenitic rutile needles.

N.20. Loc.: a hill west of Dingo Creek.

Handspecimen a dark greenish-brown rock, which occurs as a dyke in a hill near the doleritic laccolite at Dingo Creek. It contains numerous vesicles infilled with calcite. Under the microscope the main constituent is seen to be oligoclase-andesine showing Carlsbad and Albite twinning (R.I. greater than canada balsam, extinction angle 0°-10°). Hæmatite is fairly abundant through the decomposition of the original femic minerals. Opal and magnetite occur, and also some brownish, highly pleochroic aggregates and grains referable to katophorite and brownish needles referable to wöhlerite.

Name: Decomposed Phonolitic Andesite.

N.21. Loc.: dyke cutting dolerite laccolite, Dingo Creek.

Handspecimen a dark porphyritic rock with an aphanitic base. Texture hemihyaline and porphyritic.

Constituents: phenocrysts of orthoclase sanidine showing fine Carlsbad and Baveno twinning, sanidine microlites, iron ores and glass.

Name: Hemivitreous Porphyritic Trachyte.

Note: this rock is briefly described because it is important as one of the factors by means of which the relative ages of the calcic dolerite and the alkaline intrusives were determined.

Another dyke rock of the alkaline series cutting the doleritic mass is numbered N.48. It is wholly aphanitic, but microscopically porphyritic, having microlites of orthoclase sanidine, anorthoclase and oligoclase, and minute needles of greenish diopside in a noncrystalline base. Limonite occurs as a decomposition-product. This rock is a keratophyre.

N.15. Loc.: headwaters of Oakey Creek, branch of Bullawa Creek. (Plate l., fig.6; Plate li., fig.6).

Handspecimen an even-grained rock of a light grey colour, being made up of a whitish felspar and a greenish hornblende.

Texture holocrystalline, even-grained, with allotriomorphic granular fabric.

Constituents: the most abundant minerals by far are orthoclase and moirée microcline, both considerably kaolinised. Plagioclase with sericitic decomposition-products is fairly plentiful. Next in order of abundance is a greenish very pleochroic hornblende which is undergoing decomposition to magnetite and chlorite. Greenish ægirine-augite and colourless diopside are also present, as are also a few flakes of biotite with chloritic decomposition-products. A little quartz occurs interstitially. Albite is included in, and intergrown with, the orthoclase. The chief accessories are stout prisms of bluish apatite terminated with pyramids, titaniferous magnetite and ilmenite and fluorspar. Chlorite, serpentine, leucoxene and kaolin are the chief decomposition-products.

This rock, from the composition, is seen to have affinities with quartz syenite, quartz diorite, and the more alkaline augite syenites.

Name: Akerite. Magmatic name, Akerose (see Tables i. & ii.)

Note: this rock covers a great area towards the headwaters of Oakey Creek, a couple of miles above its junction with Bullawa Creek. It forms a large boss or laccolite which has been exposed by erosion. Chemically it is closely related to the dark syenite porphyries and labradorite porphyrites occurring as sills under Mount Odin.

N.32. Loc.: one-half mile W.N.W. of Ningadhun Rock.

Handspecimen a reddish, very vesicular rock, with large felspar phenocrysts. It was sectioned to determine whether it is a trachyte or andesite.

Texture holocrystalline, with phenocrysts up to 0·5 mm. long, and an extremely fine-grained microcrystalline base; fabric pilotaxitic in the base.

Constituents: andesine-labradorite felspar full of glass-inclusions, forming phenocrysts, and lath-shaped and tabular microlites of the same mineral; hæmatite replacing some hornblende; primary magnetite in minute idiomorphic grains; kaolin; a honey-yellow mineral, probably opal, and various other decomposition-products.

This rock is undoubtedly an altered andesite closely allied to the trachytes and phonolites which occur in the vicinity. Flows of these different differentiation-products occur frequently interbedded, one eruption giving a phonolitic lava, the next perhaps an andesite, the next a trachyte, and so on.

A porphyritic vesicular trachy-andesite of grey colour caps Ritter's Razorback between Bullawa Creek and Spring Creek. This rock in handspecimen seems intermediate between the andesite just described and the vesicular trachytes.

A pilotaxitic porphyritic andesite (N.33, Pl.li., fig.4) occurs around Deriah Mountain, which contains andesine-labradorite felspar; corroded, colourless diopside and light brown titaniferous augite; magnetite; ilmenite, and chlorite. This rock has also been shown to be later than the trachytes.

These andesitic rocks also form a link between the trachytes and the final basalts of the alkaline series. The first generation is felspar, usually a labradorite in highly corroded phenocrysts, round which a zone of orthoclase has frequently developed. The second generation of felspar consists of orthoclase and albite.

N.43. Loc.: at the coal seam near the basic laccolite, Dingo Creek.

Handspecimen a reddish porphyritic vesicular rock, which forms a sill a few yards thick.

Texture holocrystalline, porphyritic, with a moderately even-grained vesicular base showing flow-structure and typical trachytic fabric.

Composition: the phenocrysts are tabular and somewhat corroded, and show Carlsbad and Baveno twinning; they consist of orthoclase, and are interpenetrated with acicular microlites of another felspar, apparently albite. The base consists of acicular anorthoclase microlites, rods of hæmatite distinctly secondary after ægirine and blue amphibole; a little unchanged riebeckite and ægirine; and some primary hæmatite. A few fragments of quartz appear interstitially, and zircon occurs both as inclusions in the phenocrysts and as a constituent of the base. Nepheline does not appear to be present. Magnetite occurs in small amount.

Name: Sölvsbergite.

N.44 is a similar rock which comes from another similar sill on Dingo Creek. The felspar of this rock contains curious wavy bands and circles of another mineral, apparently quartz, intergrown with it. Both quartz and nepheline occur very sparingly in the base.

N.46 is another somewhat similar rock from a columnar mass a couple of miles N.W. of Ningadhun. This rock is also holocrystalline, and has a camptonitic fabric. The constituents are sanidine (perhaps anorthoclase), ægirine, primary hæmatite and riebeckite (or arfvedsonite). The mass is probably laccolitic.

The three rocks last-mentioned are typical of the great bulk of the trachyte of the Nandewars, and should perhaps be classed as sölvsbergites. Many of the really volcanic rocks of the flows are similar in structure and composition. The fresh rock has a flesh-colour due to primary hæmatite; on decomposition the colour changes to brick-red.

Similar rocks were met with over considerable areas at the head of Bobbiwaa Creek. Thus N.55 occurring near the base of Dripping Rock is a highly vesicular, holocrystalline, porphyritic red trachyte with trachytic fabric in the base. The constituents are felspar, probably anorthoclase, forming phenocrysts and microlites; katophorite (?), a brown highly pleochroic hornblende showing brown, red and deep blue or purple tints; ægirine; primary and secondary hæmatite, quartz; magnetite and opal.

Another specimen from this locality contains, in addition, a little tridymite, fluorite, and nepheline. After gelatinising with acid, the interstitial matter stains strongly. A little quartz is also apparently present and also cancrinite. These colourless minerals commonly contain as inclusions sagenitic rutile needles, zircon ægirite and tabular microlites of a brownish mineral.

The brown amphibole of this rock when fresh exhibits very strong pleochroism in very thin slices, but where the sections are thick the pleochroism tints are masked by a deep colour. The double refraction is likewise masked,and the mineral shows no position of extinction. In outline the mineral has the shape characteristic of arfvedsonite. It is therefore probably a katophorite. A little brownish wöhlerite (?) occurs sparingly in the rock.

All the rocks which contain the brown pleochroic mineral contain also distinct hæmatite having the same crystalline form and apparently pseudomorphic after it, not by decomposition but by alteration by pneumatolysis in the period of consolidation of the rock. Brownish minerals which are neither the one nor the other of these but conform to the same habit (either prismatic or in dendritic aggregates) also occur. These may, and probably do, belong to the allied mineral species of (1) mosandrite, rinkite and johnstrupite, and (2) wöhlerite, which are all zirconium-bearing minerals, and therefore show bluish pleochroism tints in some positions in thin sections. Those crystals which show both green and blue as well as red-brown are probably true katophorite.

N.59. Loc.: Deriah Mountain. (Plate li., fig.2).

Handspecimen indistinguishable from the trachyte of Mount Ngun-Ngun in the Glass House Mountains. It is a medium-grained, greenish-grey rock, which becomes red on weathering. It forms the whole plug of Deriah Mountain.

Texture holocrystalline, medium-grained and even grained, with trachytic habit.

Composition: the main constituents are anorthoclase felspar and sanidine. In addition we have ægirine in broken fragments of idiomorphic crystals; arfvedsonite in the characteristic aggregates; a little brown pleochroic amphibole intergrown with arfvedsonite; hæmatite, and very sparingly quartz.

Name: Arfvedsonite Ægirine Trachyte. Magmatic name, Phlegrose (*cp.* Tables i. and ii.).

N.53. Loc.: around Deriah Mountain.

Handspecimen a highly porphyritic and vesicular rock. The vesicles contain numerous decomposition-products of a zeolitic nature.

Texture holocrystalline, porphyritic, with a hyalopilitic base which is partly cryptocrystalline.

Composition: the phenocrysts consist mainly of labradorite felspar of the composition Ab_2An_3; they are idiomorphic and of prismatic habit, and are twinned on the Carlsbad, Albite and Pericline laws. Amongst the phenocrysts must also be included some very corroded phenocrysts of albite, oligoclase and orthoclase which are studded with inclusions of glass and apatite. Those of albite and oligoclase are intergrown with orthoclase at the centre. Felspar forms also the main bulk of the base, in the form of microlites of acicular habit; these needles possess straight extinction and have a refractive index lower than canada balsam; they are for the most part untwinned, but in rare cases they possess Carlsbad twinning; they may be either orthoclase or albite. Interstitially we have a brownish material which, under the high power, is partly resolved into minute round globules. The rest of the brownish material consists of glass and iron ores including some idiomorphic magnetite grains, secondary hæmatite and limonite.

Name: this rock must be referred to the trachyte family, though from the excess of plagioclase in it, it furnishes a link between the trachytes and the andesites of the locality. It is a Porphyritic-Hypocrystalline Plagioclase Trachyte.

N.51. Loc.: Dingo Creek near basic laccolite. (Plate l., fig.5).

Handspecimen white in colour, the rock occurring as a sill. It is composed almost wholly of felspar, which is of two generations, and forms more than 99 % of the bulk.

Texture holocrystalline, with phaneric phenocrysts and an aphanitic trachytic base.

Composition : the phenocrysts are clear like sanidine, but the cleavage and extinction angle (8°-10°) show that they belong to the species anorthoclase; they are twinned chiefly on the Carlsbad plan, but occasionally an albite twin is seen; some crystals show also microscopic polysynthetic twinning. Occasionally an acicular sanidine crystal is seen enveloped by a crystal of albite. Often again two sanidine laths are twinned so as to form a cross-like staurolite, each of the two individuals being itself twinned on the Carlsbad law. These are probably Baveno interpenetration twins composed of two individual Carlsbad twins. The other constituents, which occur only in minute quantity, comprise (1) interstitial rods of lemon-yellow to greenish ægirine-augite, (2) a few flakes of hæmatite, (3) occasionally a fragment of riebeckite, and (4) a few fragments of quartz.

Name: a typical Bostonite, or Sanidine-Anorthoclase Trachyte-Porphyry (*cp.* Bostonite from the Lake Champlain District, U.S.A., Kemp & Marsters, Bull. 107, Geol. Surv. U.S.A.).

N.23. Loc.: Kangaroo Valley near Ningadhun. (Plate li.,fig.5).

Handspecimen a dark basaltic rock containing huge plagioclase phenocrysts.

Texture holocrystalline, uneven-grained; fabric porphyritic, with microcrystalline hypidiomorphic-granular base.

Composition : the main constituents are felspar, augite, olivine, and magnetite. The felspar phenocrysts consist of basic labradorite; they are highly corroded, and contain magnetite and apatite inclusions. The olivine is likewise very corroded, and shows also partial decomposition to serpentine. The augite occurs as small idiomorphic grains in the base; it is a colourless or very pale greenish variety (salite). The felspar of the base is essentially albite. The base contains no olivine or basic felspar, and it consists essentially of albite, augite, magnetite, and a little apatite.

This rock is formed either by a mixture of reliquefied basic rock with alkaline lava, or by the extrusion of the last basic residuum of an alkaline magma. It is typical of a large number of varieties of very felspathic and almost olivine-free basalt and augite andesite, which occur capping the older trachytes and phonolites south of Eulah Creek. The basalt from the Sandilands Ranges, New England, is very like this rock in section and handspecimen.

I have tried in the foregoing notes to give the main features of all the rock-varieties met with in the Nandewars, rather than tedious detailed petrological descriptions of a few types, with the special object in view of inviting comparison.

All these rocks have certain features in common, from the most acid to the most basic; most striking correspondence is exhibited in

(1) The predominance of felspars rich in soda.

(2) The abundance of zirconium and titanium minerals, such as arfvedsonite, katophorite and zircon in the trachytes; wöhlerite (?), ilmenite, cossyrite (?), etc., in the phonolites; rutile and sphene in the more basic rocks.

(3) The rarity of magnesian minerals, such as olivine, even in the most basic rocks.

(4) The prevailing tendency in all to very marked porphyritic structure, and in very many to vesicular structure, even amongst sill rocks; the porphyritic structure points to a period of cooling in a deep-seated reservoir during which the minerals of the first generation formed; the vesicular structure suggests that masses of water or water-vapour (charged with mineralisers as shown by the rare minerals) gained access to the cooling mass and gave it renewed mobility, enabling it to force its way along all weak points between sedimentary beds to form sills, and to force openings to the surface, whence it flowed as lava streams.

TABLE I.—CHEMICAL ANALYSES OF ROCKS FROM THE NANDEWAR MOUNTAINS.

	N.30. Trachyte. Loc.: Mt. Ningadhun.		N.59A. Trachyte. Loc.: Deriah Mtn.		N.55. Trachyte. Loc.: nr. Dripping Rock.		N.11. Pulaskite Porphyry. Loc.: Branch of Oakey Ck. nr. Mt. Odin.		N.10. Phonolite. Loc.: Oakey Creek.		N.49. Phonolitic Trachyte. Loc.: Mt Ningadhun.	
	%	Mol.	%	Mol.	%	Mol.	%	Mol.	%	Mol.	%	Mol.
SiO_2	64·63	1·077	64·31	1·072	64·38	1·073	58·90	0·982	61·27	1·021	51·98	0·866
Al_2O_3	16·55	0·163	15·05	0·147	17·13	0·167	16·48	0·162	16·00	0·157	22·46	0·221
Fe_2O_3	2·93	0·018	3·39	0·021	5·62	0·035	2·98	0·019	2·59	0·016	2·48	0·016
FeO	1·16	0·017	2·33	0·032	0·28	0·004	3·35	0·046	4·04	0·056	1·87	0·026
MnO	0·08	0·001	0·09		—		0·08		0·10		0·08	
NiO	trace.		0·03	0·001	—		0·05	0·002	trace	0·001	0·04	0·002
CoO	abs.		p.n.d.		—		—		abs.		p.n.d.	
MgO	0·16	0·004	0·14	0·003	0·03	0·001	0·78	0·019	0·39	0·010	0·83	0·021
CaO	0·46	0·009	1·54	0·027	0·61	0·011	2·78	0·050	1·93	0·034	4·63	0·082
Na_2O	5·23	0·084	4·77	0·077	4·59	0·074	4·09	0·066	4·25	0·068	3·66	0·060
K_2O	6·11	0·065	6·59	0·070	6·49	0·069	6·05	0·064	6·31	0·067	3·93	0·041
H_2O (110°C−) ...	1·05	0·133	0·79	0·083	loss on	0·089	0·82	0·067	0·64	0·056	1·08	0·172
H_2O (110°C+) ...	1·35		0·39		ignition		0·34		0·36		2·06	
CO_2	trace		abs.		1·63		1·50	0·034	0·16		0·04	
TiO_2	0·58	0·008	1·25	0·015	0·56	0·008	1·47	0·019	1·02	0·013	4·71	0·059
ZrO_2	0·07	0·001	0·09	0·001	—		—		—		—	
P_2O_5	abs.		abs.		—		p.n.d.		p.n.d.		—	
SO_3	abs.		abs.		—		—		—		—	
Cl	trace		0·02	0·001	—		—		—		—	
F	—		0·10	0·005	—		—		—		—	
S(FeS_2)	trace*		abs.*		—*		—*		—*		—*	
BaO	abs.		abs.		abs.		abs.		abs.		abs.	
SrO	abs.		abs.		abs.		abs.		abs.		abs.	
Li_2O	abs.		abs.		abs.		abs.		abs.		abs.	
Sum	100·36		†100·98		101·32		99·67		99·06		99·85	

† Less oxygen equivalent of F 0·05=100·93.

* No pyrites detected in the slide.

TABLE I.—CHEMICAL ANALYSES OF ROCKS FROM THE NANDEWAR MOUNTAINS *(continued)*.

	N.12. Labradorite Porphyry. Loc.: Branch of Oakey Ck. nr. Mt. Odin.		N.17. Dolerite. Loc.: Laccolite, Dingo Creek.		N.18. Monchiquite Lamprophyre. Loc.: Sill, Dingo Ck.		N.15. Akerite. Loc.: Head of Oakey Ck. & Bullawa Ck.		N.62. Perlitic Pitchstone. Loc.: nr. Boggabri.	
	%	Mol.	%	Mol.	%	Mol.	%	Mol.	%	Mol.
SiO_2	51·30	0·855	47·20	0·787	36·88	0·615	56·63	0·944	66·68	1·111
Al_2O_3	16·13	0·158	11·78	0·116	4·53	0·044	17·71	0·174	13·39	0·131
Fe_2O_3	3·01	0·019	1·94	0·012	2·03	0·013	3·61	0·023	0·91	0·006
FeO	6·92	0·096	9·04	0·125	9·67	0·135	4·64	0·064	0·21	0·003
MnO	0·19 }	0·003	0·26 }		0·04 }		0·03		—	
NiO	{ 0·05 }		0·03 }	0·004	0·07 }	0·002	abs.		—	
CoO	{ p.n.d }		abs. }		abs. }		abs.		—	
MgO	2·58	0·065	9·95	0·249	25·40	0·635	1·47	0·037	abs.	—
CaO	6·97	0·125	11·63	0·207	7·61	0·136	4·06	0·072	2·72	0·048
Na_2O	4·00	0·066	1·61	0·026	1·17	0·019	5·11	0·082	2·23	0·035
K_2O	2·07	0·022	1·67	0·018	0·43	0·004	3·65	0·038	2·51	0·027
H_2O (110°C −)	0·50 }	0·133	0·28 }	0·083	0·58 }	0·078	0·49 }	0·067	{ loss on ignition	0·560
H_2O (110°C +)	1·89 }		1·24 }		0·82 }		0·70 }		{ 10·05 CO_2 being	
CO_2	1·64	0·036	0·17	0·003	8·10	0·184	0·01		{ a mere trace	
TiO_2	2·78	0·035	4·31	0·054	2·10	0·026	2·00	0·025	0·38	0·005
ZrO_2	—		—		0·06	0·001	0·06	0·001	—	
P_2O_5	p.n.d.		p.n.d.		abs.		p.n.d.		—	
SO_3	trace		—		—		—		—	
Cl	—		—		—		—		—	
F	—		—		—		—		—	
$S(FeS_2)$	—*		—*		0·17	0·006	—*		—*	
BaO	abs.		abs.		abs.		abs.		—	
SrO	trace		abs.		abs.		abs.		—	
Li_2O	abs.		abs.		abs.					
Sum	100·03		101·11		†99·66		100·17		99·08	

† Less 0·08 oxygen equivalent of S = 99·58. * No pyrites detected in the slide.

TABLE II.—NORMATIVE MINERAL COMPOSITION OF THE ROCKS OF WHICH THE ANALYSES APPEAR IN THE PREVIOUS TABLE.

N.30.
Arfvedsonite Trachyte.
Loc.: Mt. Ningadhun.

	Per cent.
Quartz	9·48
Orthoclase	36·14
Albite	44·02
Anorthite	2·50
Corundum	5·50
Zircon	0·18
Magnetite	2·32
Ilmenite	1·06
Hæmatite	1·28
Hypersthene	0·53
Water	2·40
Sum	100·43

$\frac{\text{Sal.}}{\text{Fem.}} = \frac{92·83}{5·20} > \frac{7}{1}$ Class I. (Persalane).

$\frac{Q}{F} = \frac{9·48}{82·66} < \frac{1}{7}$ Order 5. Canadare.

$\frac{Na_2O + K_2O}{CaO} = \frac{149}{9} > \frac{7}{1}$ Rang 1 (Peralkalic) Nordmarkase.

$\frac{K_2O}{Na_2O} = \frac{65}{84} < \frac{5}{3} > \frac{3}{5}$ Subrang 3 (Sodipotassic).

Magmatic name: Phlegrose,

N.59A.
Arfvedsonite Trachyte.
Loc.: Mt. Deriah.

	Per cent.
Quartz	9·84
Orthoclase	38·92
Albite	40·35
Zircon	0·18
Diopside	0·90
Wollastonite	2·09
Magnetite	3·94
Hæmatite	0·64
Ilmenite	2·28
Water	1·18
Sum	100·32

$\frac{\text{Sal.}}{\text{Fem.}} = \frac{89·29}{9·85} > \frac{7}{1}$ Class i.

$\frac{Q}{F} = \frac{9·84}{79·28} < \frac{1}{7}$ Order 5.

$\frac{Na_2O + K_2O}{CaO} = \frac{147}{0} > \frac{7}{1}$ Rang 1.

$\frac{K_2O}{Na_2O} = \frac{70}{77} < \frac{5}{3} > \frac{3}{5}$ Subrang 3 (Sodipotassic).

Magmatic name: Phlegrose.

N.55.
Hæmatite Trachyte.
Loc.: Dripping Rock.

	Per cent.
Quartz	11·70
Orthoclase	38·36
Albite	38·78
Anorthite	1·95
Corundum	1·84
Hypersthene	0·10
Hæmatite	5·70
Ilmenite	0·46
Titanite	0·78
Water	1·63
Sum	101·30

$\frac{\text{Sal.}}{\text{Fem.}} = \frac{92·63}{7·04} > \frac{7}{1}$ Class i.

$\frac{Q}{F} = \frac{11·70}{79·09} < \frac{3}{5} > \frac{1}{7}$ Order 4.

$\frac{Na_2O + K_2O}{CaO} = \frac{143}{7} > \frac{7}{1}$ Rang 1.

$\frac{K_2O}{Na_2O} = \frac{69}{74} < \frac{5}{3} > \frac{3}{5}$ Subrang 3.

Magmatic name: Liparose.

N.11.
Pulaskite Porphyry.
Loc.: Mt. Odin, Oakey Ck.

	Per cent.
Quartz	8·46
Orthoclase	35·58
Albite	34·58
Anorthite	4·45
Corundum	1·63
Hypersthene	3·22
Magnetite	4·41
Ilmenite	2·89
Calcite	3·40
Water	1·16
Sum	99·78

$\frac{\text{Sal.}}{\text{Fem.}} = \frac{84·71}{10·52} > \frac{7}{1}$ Class i.

$\frac{Q}{F} = \frac{8·46}{74·62} < \frac{1}{7}$ Order 5.

$\frac{Na_2O + K_2O}{CaO} = \frac{130}{16} > \frac{7}{1}$ Rang 1.

$\frac{K_2O}{Na_2O} = \frac{64}{66} < \frac{5}{3} > \frac{3}{5}$ Subrang 3.

Magmatic name: Phlegrose.

N.10.
Phonolitic Trachyte.
Loc.: Oakey Creek.

	Per cent.
Quartz	7·26
Orthoclase	37·25
Albite	35·63
Anorthite	6·12
Diopside	1·89
Hypersthene	3·70
Magnetite	3·71
Ilmenite	1·98
Calcite	0·40
Water	1·00
Sum	98·94

$\frac{\text{Sal.}}{\text{Fem.}} = \frac{86·25}{11·28} > \frac{7}{1}$ Class i.

$\frac{Q}{F} = \frac{7·26}{79·00} < \frac{1}{7}$ Order 5.

$\frac{Na_2O + K_2O}{CaO} = \frac{135}{22} < \frac{7}{1} > \frac{5}{3}$ Rang 2.

$\frac{K_2O}{Na_2O} = \frac{67}{68} < \frac{5}{3} > \frac{3}{5}$ Subrang 3.

Magmatic name: Pulaskose

TABLE II.—CONTINUED.

N.49. Altered Phonolitic Trachyte
Loc.: Mt. Ningadhun.

	Per cent.
Quartz	6·36
Orthoclase ...	22·80
Albite	31·44
Anorthite ...	13·62
Corundum ...	7·24
Hypersthene ...	2·36
Hæmatite ...	2·56
Titanite	6·47
Ilmenite	3·95
Water	3·14
Sum	99·94

$\frac{\text{Sal.}}{\text{Fem.}} = \frac{81\cdot46}{15\cdot34} < \frac{7}{1} > \frac{5}{3}$ Class ii.

$\frac{Q}{F} = \frac{6\cdot36}{67\cdot86} < \frac{1}{7}$ Order 5.

$\frac{Na_2O + K_2O}{CaO} = \frac{101}{49} < \frac{7}{1} > \frac{5}{3}$ Rang 2.

$\frac{K_2O}{Na_2O} = \frac{41}{60} < \frac{5}{3} > \frac{3}{5}$ Subrang 3.

Magmatic name: Monzonose.

N.12. Labradorite Porphyry.
Loc.: Mt. Odin, Oakey Ck.

	Per cent.
Quartz	3·54
Orthoclase ...	12·23
Albite	34·58
Anorthite ..	19·46
Diopside	4·08
Hypersthene ...	10·45
Magnetite ...	4·41
Ilmenite	5·17
Calcite	3·70
Water	2·39
Sum	100·01

$\frac{\text{Sal.}}{\text{Fem.}} = \frac{69\cdot81}{24\cdot11} < \frac{7}{1} > \frac{5}{3}$ Class ii.

$\frac{Q}{F} = \frac{3\cdot54}{66\cdot27} < \frac{1}{7}$ Order 5.

$\frac{K_2O + Na_2O}{CaO} = \frac{88}{70} < \frac{5}{3} > \frac{3}{5}$ Rang 3.

$\frac{K_2O}{Na_2O} = \frac{22}{66} < \frac{3}{5} > \frac{1}{7}$ Subrang 4.

Magmatic name: Andose.

N.17. Dolerite.
Loc.: Dingo Creek.

	Per cent.
Orthoclase ...	11·68
Albite	13·62
Anorthite ...	19·18
Diopside	29·42
Hypersthene ...	1·73
Olivine	12·46
Magnetite ...	2·78
Ilmenite	8·06
Calcite	0·30
Water	1·52
Sum	100·75

$\frac{\text{Sal.}}{\text{Fem.}} = \frac{44\cdot48}{54\cdot45}$ Class iii.

$\frac{Q}{F} = \frac{0}{44\cdot48} < \frac{1}{7}$ Order 5.

$\frac{K_2O + Na_2O}{CaO} = \frac{47}{69} < \frac{5}{3} > \frac{3}{5}$ Rang 3.

$\frac{K_2O}{Na_2O} = \frac{21}{26}$ Subrang 3.

Magmatic name: Kentallenose.

N.18. Monchiquite Lamprophyre.
Loc.: Dingo Creek.

	Per cent.
Orthoclase ...	2·22
Albite	9·96
Anorthite ...	5·84
Calcite	11·50
Magnetite ...	5·88
Olivine	33·96
Hypersthene ...	21·86
Ilmenite	3·95
Magnetite ...	3·02
Water	1·40
Sum	99·59

$\frac{\text{Sal.}}{\text{Fem.}} = \frac{18\cdot02}{62\cdot79}$ Class iv.

$\frac{\text{Pyrox.} + \text{Oliv.}}{\text{Mag.}} = \frac{55\cdot82}{6\cdot97} > \frac{7}{1}$ Order 1.

$\frac{P}{O} = \frac{21\cdot86}{33\cdot96} < \frac{5}{3} > \frac{3}{5}$ Section iii.

$\frac{MgO + FeO}{CaO} = \frac{770}{136} < \frac{7}{1} > \frac{5}{3}$

$\frac{MgO}{FeO} = \frac{635}{135} < \frac{1}{7} > \frac{5}{3}$ Subrang 2.

Magmatic name: Rossweinose.

N.15. Akerite.
Loc.: Oakey Creek.

	Per cent.
Quartz	2·76
Orthoclase ...	21·13
Albite	42·97
Anorthite ...	15·01
Diopside	3·56
Hypersthene ...	3·95
Magnetite ...	5·34
Ilmenite	3·80
Water	1·19
Sum	99·71

$\frac{\text{Sal.}}{\text{Fem.}} = \frac{81\cdot87}{16\cdot65} < \frac{7}{1} > \frac{5}{3}$ Class ii.

$\frac{Q}{F} = \frac{2\cdot76}{79\cdot11} < \frac{1}{7}$ Order 5.

$\frac{Na_2O + K_2O}{CaO} = \frac{120}{54} < \frac{7}{1} > \frac{5}{3}$ Rang 2.

$\frac{K_2O}{Na_2O} = \frac{38}{82} < \frac{3}{5} > \frac{1}{7}$ Subrang 4.

Magmatic name: Akerose.

N.62. Perlitic Pitchstone.
Loc.: nr. Boggabri.

	Per cent
Quartz	37·44
Orthoclase ...	15·01
Albite	18·34
Anorthite ...	13·07
Hæmatite ...	0·96
Titanite	0·20
Ilmenite	0·46
Corundum ...	2·24
Water	10·05
Sum	97·77

$\frac{\text{Sal.}}{\text{Fem.}} = \frac{86\cdot10}{1\cdot62} > \frac{7}{1}$ Class i.

$\frac{Q}{F} = \frac{37\cdot44}{46\cdot42} < \frac{5}{3} > \frac{3}{5}$ Order 3.

$\frac{Na_2O + K_2O}{CaO} = \frac{62}{47} < \frac{5}{3} > \frac{3}{5}$ Rang 3.

$\frac{K_2O}{Na_2O} = \frac{27}{35}$ Subrang 3.

Magmatic name: Riesenose

Discussion of the Analyses.

The chemical examination of the Nandewar rocks was conducted in the Chemical Department, Sydney University, and I am indebted to Professor Liversidge and Mr. Schofield for having placed apparatus at my disposal.

The alkaline rocks analysed all belong to the intermediate group. Yet there are both acidic and basic alkaline rocks in the district which were not analysed, having been satisfactorily determined microscopically.

Three of the rocks analysed, namely, dolerite from Dingo Creek (N.17), lamprophyre, Dingo Creek (N.18), and perlitic pitchstone, Boggabri (N.62), exhibit no definite relationship with the alkaline series.

The lamprophyric rock probably has a monchiquitic base. Felspar is very rare; most of the Al_2O_3 exists in the spinel (pleonaste). The alkali not having sufficient Al_2O_3 to form felspar, has gone to form analcite. This rock might indeed be best regarded as the result of a kind of magmatic mixture in which an alkaline magma has burst through a very basic mass, and carried along in it fragments of peridotite (xenoliths) and xenocrysts of spinel and hypersthene. The occurrence is strictly analogous to that which has been described by Mr. C. Süssmilch, F.G.S., for the Bombo Quarries near Kiama.*

In both instances, too, we have an alkaline rock (at Kiama, an orthoclase basalt†) carrying these basic xenoliths. Mr. C. Süssmilch has kindly shown me his specimens, and the resemblance to mine is very striking. A similar occurrence has been described at the Pennant Hills Quarry.‡

The chemical analysis of the Boggabri pitchstone gives no clue as to whether this rock is of the same age as the trachytes or not, a matter for which I had insufficient field-evidence to decide.

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* "On the Occurrence of Inclusions of Basic Plutonic Rocks in a Dyke near Kiama." Journ. Proc. Roy. Soc. N. S. Wales, Vol. xxxix.

† "Geology of the Kiama-Jamberoo Districts." Rec. Geol. Surv. N. . Wales, Vol. viii.

‡ Journ. Proc. Roy. Soc. N. S. Wales, 1893.

All the other analyses are of alkaline rocks. The trachytes from Ningadhun (N.30), Deriah Mountain (N.59), and Dripping Rock (N.55) are very similar in chemical composition, and are also closely allied to the arfvedsonite trachytes of the Warrumbungles, to my analyses of which attention is directed. They all lie on the borderlines between the subrangs of Phlegrose, Nordmarkose, and pulaskose of the quantitative classification.

The dark sill rocks N.11 (Pulaskite Porphyry), N.10 (Phonolitic Trachyte), and N.12 (Labradorite Porphyry) are of considerable interest. The specimens analysed containing no calcite, the CO_2 present is contained in the secondary minerals pseudomorphic after nepheline, namely hydronephelite, liebnerite and geisekite. The Pulaskite Porphyry is in handspecimen almost as dark as a basalt (dark green), and would not be judged to be of very nearly the same composition as the light-coloured trachytes. Microscopic examination, however, reveals that the felspar is essentially anorthoclase and microcline microperthite, and that ferromagnesian minerals are not abundant. The chemical analysis makes the position of the rock still more certain, and the norm fixes its magmatic name as phlegrose, the same as the arfvedsonite trachytes.

The analysis of N.15 shows that this rock chemically as well as structurally is akerite.

The altered nepheline phonolite, N.49, was analysed because it contained the same doubtful minerals as the corundum-basalt from Billy King's Creek (W.40) in the Warrumbungle Mountains. The analysis suggests that their determination as corundum and laavenite is correct. In the quantitative system this rock has the magmatic name monzonose, and contains quartz in the norm, which differs in a remarkable way from the mode.

Determination of P_2O_5.—This constituent was not determined in any of the rocks analysed from the Warrumbungle and Nandewar Mountains, as it was found that utterly unreliable results were obtained. The amount of P_2O_5 in all these rocks would be very small, in those where apatite is most abundant, such as the dolerite (N.17) and the akerite (N.15) reaching a maximum of perhaps 0·50 %, whilst in the trachytes it would be practically absent. By taking 0·0025 gram of microcosmic salt containing about 0·0005 gram of P_2O_5, precipitating in the usual way with ammonium molybdate, redissolving the precipitate and precipitating as magnesium phosphate, a precipitate weighing 0·0050 gram was obtained, equivalent to 0·0030 gram of P_2O_5.

This I attribute to the following cause, viz., the ammoniacal solution containing the magnesium phosphate in standing 24 hours takes up the carbon dioxide from the air and silica from the glass vessel, with the result that one weighs basic magnesium silicate and carbonate with the phosphate. Error from this cause can only be avoided by letting the solution stand in a platinum vessel in a carbon-dioxide-free atmosphere.

It was also noticed that, in following Washington's method of decomposing the rock with nitric and hydrofluoric acid, in the part used for determining P_2O_5, no precipitate was obtained with P_2O_5 without warming, although the rocks might contain apatite equivalent to between 0·05 and 0·25 % of P_2O_5; further, on warming, too much molybdate precipitate is generally obtained. These irregularities are *probably* due to the presence of traces of HF, which hinder the formation of the phosphomolybdate; and, on warming, to the formation of a certain amount of silico-molybdate; but the matter needs looking into.

In the face of these difficulties and as P_2O_5 was an unimportant constituent in the rocks which I was examining, I did not consider it worth my while to devise a method for overcoming the difficulties. It is very possible that inexperienced analysts often follow the text-book methods without enquiring into their accuracy; and, not observing the many precautions necessary, get high results for P_2O_5. The amount of this constituent given in many analyses of trachyte, phonolite and granite seems absurdly high. The smaller the actual quantity of P_2O_5 in a rock, the more exaggerated the error becomes.

As accuracy in rock-analysis is daily becoming more important, it would be well if some chemist could take up the matter of devising a good laboratory method for determining P_2O_5.

The Differentiation of the Nandewar Rocks.

A glance at the analyses will serve to show that in the alkaline rocks there is a gradation both mineralogically and chemically. If any one of them can be considered to represent the parent-magma, it must be the pulaskite porphyry, N.11.

	Trachyte N.30. Ningadhun.	Labradorite Porphyry, N.12.	Mean of N.30 and N.12.	Pulaskite Porphyry, N.11.
SiO_2 ...	64·63	51·30	57·97	58·90
Al_2O_3 ...	16·55	16·13	16·34	16·48
Fe oxides..	4·09	9·93	7·01	6·33
MgO ...	0·16	2·58	1·37	0·78
CaO ...	0·46	6 97	3·71	2·78
Na_2O ...	5·23	4·00	4·61	4·09
K_2O ...	6·11	2·07	4·09	6·05
TiO_2 ...	0·58	2·78	1·68	1·47

The phonolites (represented by N.10, analysed) have almost the same composition as the pulaskite-porphyry. The akerite is a special differentiation-product, the complementary type of which I have not met with. It is nevertheless not far removed from the mean of N.30 (trachyte) and N.12 (labradorite porphyry) given in the above table. In fact it will be easily observed that if that mean be regarded as the composition of the parent-magma (Haupt-magma) the akerite and pulaskite porphyry are complementary forms on either side of it.

	Akerite.	Pulaskite Porph.	Mean.	Haupt-Magma.
SiO_2 ...	56·63	58·90	57·76	57·97
Al_2O_3 ...	17·71	16·48	17·09	16·34
Fe oxides..	10·25	6·33	8·29	7·06
MgO ..	1·47	0·78	1·12	1·37
CaO ...	4·06	2·78	3·41	3·73
Na_2O ..	5·11	4·09	4·60	4·61
K_2O ...	3·65	6·05	4·85	4·09
TiO_2 ..	2·00	1·47	1·73	1·68

The pulaskite-porphyry is also interesting as being in chemical composition very near to the trachy-andesites (monzonose) of the

Warrumbungle Mountains, to grey laurvikite from Laurvik (Norway), to umptekite, Red Hill (New Hampshire), and to rhombenporphyr, as the following table shows.

Monzonose, W.1, Warrumbungles.		Pulaskite Porphyry, N.11.	Laurvikite, Laurvik.	Umptekite, Red Hill.	Rhomben-porphyr, Norway.
SiO_2 ...	58·95	58·90	58·88	59·01	58·54
Al_2O_3 ...	17·80	16·48	20·30	18·18	17·28
Fe oxides...	7·46	6·33	6·22	5·28	8·61
MgO ...	0·57	0·78	0·79	1·05	1·81
CaO ...	2·49	2·78	3·03	2·40	3·04
Na_2O ...	4·51	4·09	5·73	7·03	7·18
K_2O ...	6·39	6·05	4·50	5·34	3·24
TiO_2 ...	0·76	1·47	det. with Al_2O_3	0·81	—

The rock under discussion differs from laurvikite in containing less lime and alumina; it contains relatively less alkali than umptekite, and less silica than typical pulaskite. It is best considered to be a basic facies of pulaskite. *What is particularly striking is that it appears that the parent-magma of the Nandewar alkaline rocks is the same as that of the Warrumbungle rocks.*

The Quantitative Classification of Igneous Rocks.

Of late years there has been a good deal of discussion as to the merits of the quantitative classification and magmatic nomenclature devised by Iddings, Washington, Pirsson and Cross. A few remarks on this subject will not be out of place here.

The quantitative system has done excellent work in waking up petrologists to the value of rock-analysis. Analyses of rock-types and of rocks difficult to classify are essential both for correct identification and for arriving at conclusions regarding magmatic differentiation. Further, for purposes of comparison, the calculation of the norm is invaluable. Take, for instance, the analyses of N.30 and N.11 in Table i. The microscope revealed affinities between these rocks, sufficiently to enable one to say that both belong to the alkaline group. The analysis brings their affinity into more marked prominence. But it is only when we compare their calculated norms that we see how closely allied they are. The calculation of the norm in terms of standard minerals is a great boon for purposes of comparison, and having the analysis we can also calculate it in terms of other mineral-combinations, and thereby ascertain what other rock-species might arise from the same magma.

As for the classification based on the norms, it must be said that it is no better than previous classifications. Whether we call a certain rock syenite-porphyry, phlegrose, or nordmarkite, we must first know the chemical and mineralogical composition corresponding to these names; and the Rosenbusch and Brögger names have the advantage over the magmatic names that they define the mineralogical composition much more accurately, and give us some idea of texture, fabric and facies as well.

As Professor Marshall* of Dunedin and many others have shown, the quantitative system brings together, under a common name, rocks which are widely different, and separates closely allied ones.

This is strikingly exemplified in my studies on the petrology of the Warrumbungle and Nandewar Mountains. Thus the labradorite porphyry (N.12) is seen from field-evidence and microscopic examination to be a differentiation-product of a pulaskite magma. There are many analogies in the mode of occurrence and the composition and structure of the groundmass to bind it to the alkaline series. Yet the fact that it is chemically poorer in alkali and richer in lime and magnesia than the other members of the series removes it so far as to place it in the subrang "andose," whereby its alkaline affinities are completely obscured.

Now N.15, a quartz-monzonite or akerite, an olivine-free rock, of light grey colour and even grain-size, has the same magmatic name as the orthoclase-sodalite-basalt, W.67, from the Warrumbungle Mountains (p.607), although the last-mentioned is a black,

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* "Geology of Dunedin." Q.J.G.S. Vol.lxii.

basaltic, uneven-grained rock, containing olivine and titaniferous augite. Truly both these rocks are alkaline, but their facies, mode of occurrence, constitution, and origin are all so different that the system of classification which brings them together is most unnatural. The one type, N.15, is a hypabyssal rock derived by magmatic differentiation from an alkaline magma; the other is a volcanic rock which originated by *magmatic mixing.*

A system of rock-classification cannot be both chemical and mineralogical, and an attempt to create such a system must be futile. To separate the lime combined with alumina from that of diopside, calcite, and apatite in estimating the rang is also unnatural.

Personally, I favour adherence to the old nomenclature, but believe as well in having as many analyses as time will permit. To determine the norm is also highly desirable. A chemical analysis is almost as quickly made as Rosiwal measurements, and is much more reliable than calculating the norm from the mode.

Further, Rosiwal measurements are sheer waste of time unless the rock to be studied is *medium-* or coarse-grained, and of fairly even grain-size; in addition, its minerals should be of definite and known composition (as in granite and gabbro).

Volcanic Sequence.—As already stated the sequence observed in the Nandewar Mountains was—

(1) Injection of basic laccolites and sills as N.17; after which prolonged denudation.

(2) Eruption of arfvedsonite trachytes (N.30, N.59, N.55, etc.) and their tuffs.

(3) Earth-movements and intrusion of sills of pulaskite and nordmarkite porphyry, accompanied by eruptions of phonolite (N.11, N.10, N.49).

(4) Eruptions of andesite followed, and the sills of labradorite porphyry being of andesitic composition probably belong to this phase of activity (N.12).

(5) Flows of alkaline basalt, followed by normal basalt.

EXPLANATION OF PLATES.

Plate xlvi.

Geological Sketch Map of the Nandewar Mountains, and the country between the Nandewars and New England.

Plate xlvii.

Geological Sketch Map of the Nandewar Mountains only. Scale approximately 4 miles to the inch.

Plate xlviii.

Fig.1.—View of Ningadhun and Yullundunida from the Bullawa Creek Valley.

Fig.2.—View of the same from a point higher up in the hills. Sandstone formation in the foreground.

Plate xlix.

Fig.1.—View of the Lindesay Group from Bullawa Creek, five miles from the mountains.

Fig.2.—Scabby Rock, Pilliga Scrub.

Plate l.

Microphotographs of Nandewar Rocks (× 14, except fig.6 of Plate l., and fig.3 of Plate li.).

Fig.1.—Perlitic Pitchstone; Boggabri (N.62); nicols uncrossed.

Fig.2.—Dolerite; Dingo Creek (N.17); nicols uncrossed: the extinguished crystal is augite; the smaller bright crystal near it olivine.

Fig.3.—Sölvsbergite, Bullawa Creek (N.8), showing microperthitic felspar phenocrysts; nicols uncrossed.

Fig.4.—Pulaskite Porphyry; Oakey Creek (N.11); showing phenocryst of microcline microperthite near extinction, with zone of orthoclase.

Fig.5.—Bostonite; Dingo Creek (N.51); nicols crossed. Note peculiar cruciform twin.

Fig.6.—Akerite; Oakey Creek (N.15); nicols uncrossed. Note ægirine augite phenocryst (× 21).

Plate li.

Fig.1.—Labradorite Porphyry (N.12); nicols crossed.

Fig.2.—Arfvedsonite-Ægirine Trachyte (N.59); nicols uncrossed.

Fig.3.—Monzonose (phonolitic) (N.49); nicolls uncrossed (× 21).

Fig.4.—Andesite with Labradorite phenocrysts (N.33); near Deriah; nicols uncrossed.

Fig.5.—Phenocryst of Labradorite in alkaline basalt (N.23); nicols crossed.

Fig.6.—Akerite (N.15); nicols crossed.

Plate lii.

Figs.1*a*-*b*.—Handspecimen of Monchiquitic Lamprophyre.

Fig.2.—Handspecimen of Labradorite Porphyry.

(The figures of this Plate from photos by H. Gooch).